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Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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CORRIGENDA.

Page xcii, line 13 from bottom, *for* 'William' *read* 'Walter.'
Page 117, line 11 from top, *for* 'south' *read* 'north.'

Vol. LI. FEBRUARY 1st, 1895. **No. 201.**
PART 1.

THE

QUARTERLY JOURNAL

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TO BE HELD AT BURLINGTON HOUSE.

SESSION 1894–95.

1895.

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	(*Anniversary*) Friday, February 15th.	
„	March	6–20
„	April	3–24
„	May	8–22
„	June	5–19

[*Business will commence at Eight o'Clock precisely each Evening.*]

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

Vol. LI.

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1. Notes *on some* Recent Sections *in the* Malvern Hills. By A. H. Green, Esq., M.A., F.R.S., V.P.G.S., Hon. Fellow of Caius College, Cambridge, and Professor of Geology in the University of Oxford. (Read November 7th, 1894.)

The main mass of the Malvern Hills consists, as is well known, of crystalline schists and massive igneous rocks which we may with safety admit have an Archæan aspect. These have been largely studied; but at one spot at least there are rocks of a very different character, which have hitherto received scant attention. They occur on the eastern side of the Herefordshire Beacon. The summit-line of the ridge runs generally north and south, but here it takes a bend away to the west, and encloses an amphitheatre-like recess, in which stands a group of lower hills known as Tinker's Hill, Broad Down, and Hangman's Hill, that are composed of the rocks in question.

It will be convenient to give them a name, and they may be called shortly the 'Warren House Rocks,' after a farm in the recess.

These rocks have not been altogether overlooked by former observers. Prof. Phillips must have been aware of their existence, for in the Oxford Museum I have found a few specimens of them collected by him. He realizes, but does not lay stress upon the fact that they differ in character from the rocks of the greater part of the Malverns.[1]

The area which these rocks cover is correctly delineated by Dr. Holl; he describes them as 'Altered Primordial Rocks and Post-primordial Trap.'[2]

Among the rocks analysed by the Rev. J. H. Timins are some belonging to this group.[3]

[1] Mem. Geol. Surv. vol. ii. (1848) pt. i. pp. 30, 31.
[2] Quart. Journ. Geol. Soc. vol. xxi. (1865) plate facing p. 72.
[3] *Op. cit.* vol. xxiii. (1867) p. 352.

Mr. Rutley has described some rocks from this group.[1] He states in the latter paper that these rocks form 'a buttress faulted against the eastern flank of the Herefordshire Beacon' (p. 743); but he gives no evidence for the existence of the fault.

Recently a reservoir for supplying water to Great Malvern has been constructed in the valley between Tinker's Hill and Broad Down, and the excavations made in the course of this work have opened out the rocks in question and thrown some little additional light on their character and lie.

My attention was drawn to these cuttings by Prof. Hughes in 1892, and during the summer of that year I gave some time to a study of them and the surrounding country, with, I fear, slender results; but, as most of the sections are now covered up, it seemed worth while putting on record what they showed; and this must be my excuse for troubling the Society with a paper which is little more than a statement of facts, and leads but to meagre conclusions.[2]

The rocks are bedded. In the puddle-trench of the reservoir they strike about north, and are nearly on end. In the cutting for the diverted road along the south-western side of Tinker's Hill the strike is still northerly, but the dip comes down to 75°, and a little farther south-east is only 25°. Whether the same strike is maintained over the whole tract we are concerned with cannot be definitely asserted, for the great bulk of the rocks are very much alike, and no beds occur which have distinctive individuality enough to enable them to be traced with certainty across the open country. In some few cases my attempts at detailed mapping have been attended with qualified success; and, if my tentative identifications be correct, the general strike is north and south.

Of the rocks themselves it is impossible to speak with satisfaction. The great bulk of them are hard, closely grained, and splintery, such as could be conveniently grouped in the field under the vague term of 'felsites.' Of these some under the microscope have much that is rhyolitic about them, and are not improbably lavas, some perhaps devitrified glasses. Others are seen to be decidedly fragmental, and may well be tuffs. They are largely altered, so thickly veined with calcite in many cases that they effervesce freely with acids. This seems to have led some observers to call them limestones, but a little attention shows that in nearly all the effervescence is confined to the veins. Epidote in veins and disseminated through the rock is also common.

There are also dolerites, some of which are not unlike the felsitic rocks macroscopically, but are clearly characterized under the microscope. Whether these are flows or intrusive sheets is an open question; I rather incline to the opinion that they are intrusive, for, as will appear later on, they seem to be wedge-shaped masses and not continuous beds.

[1] Quart. Journ. Geol. Soc. vols. xliii. (1887) pp. 498, 499, & xliv. (1888) p. 740.

[2] I acknowledge, with many thanks, the assistance which I have received from my friends, Mr. Rutley and Mr. Teall, in my examination of the rocks dealt with in this paper.

A few details as to the distribution of the rocks may now be given.

Along the western boundary of the area there is a broad strip of ground occupied by dolerite. A specimen from Clutter's Cave has been figured and described by Mr. Rutley.[1] He says that the felspars are chiefly labradorite, in laths generally corroded and frequently bent; augite appears in irregular grains, few distinct crystals; ilmenite and white opaque matter, probably leucoxene, and pyrites in very minute specks occur; also a small vein of epidote. I have only to add that in my slide there are vesicular cavities filled with a zeolite-like mineral. For about 10 chains north and 20 chains south of the Cave all the rocks seen have a strong general resemblance to this one. They vary in grain and in the relative proportions of the component minerals, but they are sufficiently near one another to make it possible that they may all belong to the same mass.

Analyses xxxvi. to xxxviii. of Mr. Timins's paper give the composition of the rock at the Cave and rocks in its neighbourhood.

East of this dolerite there is a belt of ground over which many of the rocks have a fragmental aspect. In some slides angular chips of quartz and felspars are bedded in fine dust; others consist entirely of fine dust, but their fragmental character is fairly obvious. Rocks of this character, lying on the same strike, run from Broad Down on to Hangman's Hill; they are probably tuffs. On the south side of Hangman's Hill, 200 yards east of Hill Cottage, there is a very conspicuous crag. The rock from this is crowded with small grains of magnetite and slender laths of felspar. A very similar rock occurs about 100 yards to the north, in which a crystal or two of augite remain unaltered. These rocks resemble very closely the matrix of some of the lavas of Etna. No rock like this has been detected elsewhere in the area, a fact which suggests that it may be intrusive.

Going now eastward, we come on to another belt of dolerite, not differing essentially from the rock of Clutter's Cave. It was seen in the cuttings made for enlarging the reservoir on its northern bank, and a similar rock seemed to run along the same strike across Broad Down. It appeared to die out before reaching the valley between Broad Down and Hangman's Hill; and the rocks on the same strike south of that valley are of a totally different character.

The rocks that follow to the east are of rather a perplexing character, and many of them largely decomposed. A hard bed stood up towards the northern end of the puddle-trench, and a rock of the same character was seen on the same strike in the cutting for the pipe-track. It is a very problematical rock. There may be an isotropic base, but the doubly-refracting particles lie so thick that it is difficult to be sure of this. The doubly-refracting grains are small, have most of them no definite outlines, and polarize in dull grey tints. There is a strong rhyolitic aspect, and this is probably

[1] Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 498, pl. xx. fig. 9, & pl. xxi. figs. 4, 5.

the character of the rock. Another band, somewhat coarser in grain, but otherwise similar to the last, I was able to trace from the south-western side of Tinker's Hill, across the valley, on to Broad Down. Many other rocks of a similar character, some banded and showing ill-defined fluxion-structure, occur along the same belt.

East of these a rock with fragmental texture occurs on the northern side of Broad Down, and a rock very similar in character crops out on the same strike on the southern side of that hill. I think that no one possessing a reasonable amount of caution would speak with certainty about the rocks of this belt; but the probability is that we have here a series consisting of alternations of rhyolitic lavas and tuffs. The exact localities of the specimens analysed by Mr. Timins cannot be fixed, but it is not unlikely that nos. xli. to l. belong to this belt. In it lies the rock in which Mr. Rutley believes that he detected perlitic structure.

A very singular rock belonging to the same belt was exposed in the cutting for the diverted road. The matrix may contain some isotropic matter, but it is thickly crowded with very minute doubly-refracting grains and hairs. Its peculiarity consists in the presence of a large number of ring-shaped patches, edged with a mineral that polarizes in brilliant colours, the centre of each ring being like the matrix, but rather darker in colour. This rock was analysed for me by Mr. R. Hornby (Queen's College, Oxford). As it was thickly veined with calcite the powder was first treated with cold dilute hydrochloric acid for 24 hours. The insoluble residue had the following composition:—

Silica	78·41
Iron and alumina	16·38
Magnesia	0·88
Lime	0·55
Alkalies, by difference	3·78

My friend Mr. Rutley has spent some time over this rock, but without coming to any definite conclusion as to the meaning of its peculiarity.

Next follows a belt of dolerite, which resembles the rock of Clutter's Cave. It was well shown in the cutting for the diverted road at the south-western end of Tinker's Hill, in a quarry on the opposite side of the valley, and in the cutting for the catchwater. It is traceable up to the summit of Broad Down, and indications of a similar bed on the same strike were seen on the southern slope of that hill. The bed seemed here to be thinner than on Tinker's Hill, and I could find no trace of it on the opposite side of the valley on Hangman's Hill. At one spot on Tinker's Hill Mr. H. D. Acland called my attention to parts of this bed which are vesicular and amygdaloidal.

East of the band of dolerite last described the rocks look, to the unaided eye, very much alike—hard, splintery, and felsitic in aspect. Those which I have examined under the microscope are some of them fragmental, while others have the rhyolitic character of the rocks to the west. Probably we have here a second belt of rhyolitic lavas and tuffs.

So far, then, as I dare have an opinion, I am inclined to think that we have here a group of bedded acid lavas and tuffs, crossed by three bands of dolerite.

The question arises whether these dolerites are flows or intrusive sheets. What little balance of evidence there is seems to me to be in favour of their being intrusive. Though they are fairly well marked in appearance and not difficult usually to distinguish from the felsites, I have not been able to trace them across the whole of the area; they show vesicular structure only very sparingly, and I have not recognized fluxion-structure in them.

One rock different from any yet noticed deserves mention. It was cut into at the north-western corner of the excavation for the filter-beds, and a rock exactly identical with it was noticed 100 yards south-west of Warren House. It is a dull-white granular rock, speckled with soft greenish needles and spots. Under the microscope the matrix is seen to consist of quartz-granules, decomposed felspathic matter, and grains of magnetite. In this lie long needles of a soft greenish decomposition-product, and large crystals of decomposed felspar, some of which are triclinic and some may be orthoclase. The line joining the two points where this rock was seen runs a little north of west. It is probably a dyke. Mr. Harker looks upon the rock as a much decomposed mica-lamprophyre.

The large amount of calcite in many of the Warren House rocks led me to keep a look-out for limestone. The following are the only cases in which I detected rocks that in the least deserve this name; partial analyses were made of them for me by Mr. R. Hornby.

A calcareous nodule was noticed in one of the beds cut through in the pipe-track. It effervesced briskly with cold acid all over, and contained 56·40 per cent. soluble in cold dilute hydrochloric acid, chiefly calcium carbonate. The microscope shows that, besides the numerous veins of calcite, the whole rock is permeated by what appears to be that mineral; but there are angular grains of quartz, and some perhaps of felspar. The rock in which this nodule lay has a matrix, which may be isotropic, thickly set with a tangled mass of hairs and grains of doubly-refracting mineral, and containing blebs of quartz and some larger crystals of felspar; it is thickly veined with calcite, but effervesces only along the veins.

A similar nodule was noticed in a bed in the cutting for the diverted road. It contained 38·57 per cent. of soluble matter, nearly all calcium carbonate. The microscopic slide shows a mass of broken felspar-crystals, chips of quartz, and patches of a green decomposition-product, the interstices between these being filled up mainly by calcite. It has the look of a decomposed tuff permeated by calcite.

In both these cases it was perfectly clear that we were dealing with a single isolated nodule, and that there was no bed of limestone, not even a string of nodules. They would seem to be cases in which calcareous matter has been introduced into a rock and aggregated round certain centres. Some large calcareous nodules of

a similar character were dug out of loose decomposed surface-rock at the western end of the reservoir.

A calcareous bed was cut through towards the northern end of the puddle-trench, which contains 65 per cent. of calcium carbonate. About one half of it is seen under the microscope to be made up of strings and ramifying masses of what is probably calcite; the remainder is transparent and structureless, and polarizes in a dark-grey colour.

An adjoining bed has evidently been originally a crystalline rock, for the outlines of the crystals are still visible, though they are too decomposed to be identified. It contains what seems disseminated calcite, but in much smaller quantity than the last rock, and its analysis yields only 13 per cent. of calcium carbonate.

It looks as if we had here two rocks belonging to the volcanic group, one of which has been very largely and the other slightly calcified.

I deferred the publication of these notes in the hope that I might be able to find elsewhere in the Malverns rocks similar to those of the Warren House area. I cannot say that even now my examination of the hills has been exhaustive; but I have been over the whole of them, and have found rocks which bear some resemblance to those just described at two spots only. One is on the southern part of Raggedstone Hill. We have here rocks which have a bedded aspect, and some of which have externally a felsitic appearance resembling that which prevails so largely among the Warren House group. The general resemblance between the two was noticed by Prof. Phillips (Mem. Geol. Surv. vol. ii. pt. i. p. 26); it is hardly so close as appears at first sight.

The accompanying figure shows the section along a line running due east from the Trigonometrical Station.

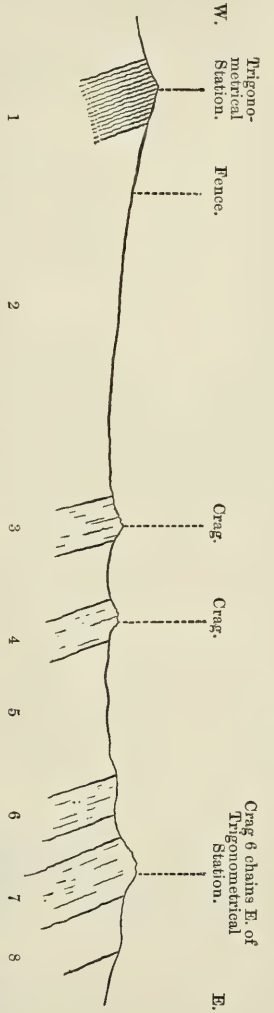
No. 1 is pale grey, soft, micaceous schist. The space No. 2 is grass-grown. No. 3 has a crushed and rolled-out look; it contains wavy films of a chloritic mineral; streaky bands of quartz showing strong strain-shadows; felspar, some triclinic; augite, and (?) epidote. It may well be a crushed and sheared dolerite. No. 4 contains fibrous hornblende, shattered felspar, and much disseminated limonite. Mr. Teall tells me that it is very like some Cornish epidiorites. No. 5 is confused by a network of quartz-veins. No. 6 scarcely differs from No. 3. No. 7 is a felsite; it shows no signs of mechanical deformation, and it may be intrusive. No. 8 and another rock a little farther east are epidiorites, which Mr. Teall tells me are like some Cornish rocks that have resulted from the alteration of gabbros. Slides taken from bosses a little north of the line of section and some way to the south are practically identical with No. 3. Another rock south of the line of section consists of rolled-out quartz and felspar-grains foliated by thin films of mica; it is just such a rock as would be produced by the shearing of No. 7.

In a quarry 20 chains south-east of the Trigonometrical Station the upper beds consist of green fibrous hornblende, torn and wrenched and dragged out into wavy films, and plagioclase. There is probably a little augite, so this is most likely an epidiorite. The bottom bed is

a quartz-schist slightly foliated by chloritic films; it seems to contain too much quartz to be an igneous rock. The dip along the section in the figure is due east; in the quarry last mentioned it is north-east.

The rocks of this group differ in several respects from those of the Warren House area. They are more basic in composition; out of twelve examined only two can be called felsites; and they have been subjected to very considerable mechanical deformation. No signs of crushing or shearing, and no strain-shadows, occur in the Warren House rocks; in all but one of the rocks of Raggedstone Hill these are palpably apparent.

I am unable to say whether these rocks are among those dealt with by Dr. Callaway in his last paper on the 'Origin of the Crystalline Schists of the Malvern Hills,'[1] because I cannot identify his localities with any certainty. But though the rocks I have been speaking of may well be on the road to become schists, they are all of them very far from having arrived at that consummation.



Section across the north-eastern part of Raggedstone Hill.

Relation to the Crystalline Schists.

Unfortunately, neither in the Warren House area nor on Raggedstone Hill have we anywhere a junction or anything like a junction shown between the special rocks of these districts and the schists that make up the main mass of the hills.

Several hypotheses present themselves as to the relationship between the two. The Warren House rocks may be totally distinct from the schists. If this be so, the absence of mechanical deformation in them would indicate that they are the younger. If we accept the view that the schists of the Malverns have been formed by dynamic metamorphism out of volcanic rocks, the rocks of Raggedstone Hill may be a portion of this volcanic complex which has undergone only partial transformation. And there is again the possibility that the Warren

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) pp. 401 *et seqq.*

House rocks may be a part of the complex that has altogether escaped metamorphism, that the Raggedstone Hill rocks are a part in which metamorphism has been arrested at an early stage, while the schists represent the final step in the process.

The only other rock that need be mentioned here forms an isolated boss south of Chace-end Hill, 30 chains north of Bromsberrow Place. It is reddish and brecciated, and all one can say about it is that it is a shattered felstone thickly impregnated with limonite. There is nothing to show its relationship to the adjoining rocks.

[I had forgotten to state that Mr. J. F. Bryant has made a study of the Warren House rocks, and has kindly furnished me with a copy of Mr. Harker's notes on his slides, which the Author has given me leave to quote. Mr. Harker says:—"The rhyolites are just like many in North Wales, and the ashes with rolled bits of lava could be matched there, and especially in the Lake District."—December, 1894.]

Discussion.

Mr. Watts asked whether the rocks were the same as those described by Dr. Callaway.

Dr. Hicks was glad that Mr. Watts had called attention to Dr. Callaway's researches amongst these rocks. He had gone over these sections some years since under Dr. Callaway's guidance, and found that the rocks resembled in a marked manner the Pebidian rocks of St. David's.

Mr. Rutley said that he agreed in almost every respect with the Author's statements. The rocks occurring in this small area were lavas of acid and basic characters, associated with tuffs. The felsitic lavas sometimes contained epidote, at others calcite, the latter mineral being often present in considerable quantity. The structures in these lavas were exceedingly obscure. That these volcanic rocks were totally distinct from the crystalline schists which constitute the main mass of the Malvern range, there could, he thought, be no doubt whatever; and of the different hypotheses alluded to by the Author, he was inclined to adopt that of the volcanic rocks being of later age than the crystalline schists—a view which led to the inference that the former had been let down between faults. While admitting that various parts of the range showed evidence of having been affected by pressure and earth-movements, he did not agree with Dr. Callaway in considering that the stresses had resulted in shearing, except on a very limited scale in certain zones.

Mr. Harker testified to the resemblance of the rocks from the new reservoir at Malvern to the old acid lavas of Caernarvonshire. He had had the opportunity of studying a series of rocks collected from that locality by Mr. J. F. Bryant. The type is well characterized by its containing only a few scattered porphyritic crystals of plagioclase (without quartz or any ferro-magnesian mineral) in a cryptocrystalline groundmass. Among newer rocks this type is represented by the rhyolites of Iceland.

The Author replied.

2. *The* Denbighshire Series *of* South Denbighshire. By Philip Lake, Esq., M.A., F.G.S. (Read November 7th, 1894.)

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I. Introduction.

There are few series of rocks in the southern half of Great Britain which have been so much neglected by geologists as the Denbighshire Grits and Flags; and the reason is not far to seek. As a rule, these rocks form rounded hills which are often completely covered with heather, and there are many square miles of country without a single exposure. The beds are frequently much folded and faulted, and it is often a work of great difficulty to make out their relations to each other. Fossils are by no means common, except in a few localities; and the most important are graptolites, which the earlier geologists considered to be of little value for stratigraphical purposes. Under such circumstances it is not surprising that these rocks have tempted few geologists to enter the field, and that the observations which have been made on them have in general been somewhat cursory.

The series, nevertheless, deserves more than a passing notice. It belongs to one of the most widely-spread facies of the Silurian in Britain; and now that the stratigraphical value of graptolites is so generally recognized, it has become a matter of some interest to see how far these graptolite-bearing deposits correspond with those of other regions.

The area over which my observations have extended includes the whole of what may be called the Llangollen basin; but the present paper is occupied chiefly with that part in which the beds are best exposed and in which the succession is clearest—that is to say, the south-western quarter of the basin.

II. Literature.

It was in 1840–41 that J. E. Bowman[1] published the first account of the Silurian rocks of the Vale of Llangollen. In the main his description is tolerably accurate, but he does not appear to recognize that the flaggy beds overlie the slates [Pen-y-glog Slates] which are

[1] Brit. Assoc. Rep. of Sects. 1840 (Glasgow), p. 100; *ibid.* 1841 (Plymouth), p. 59; Trans. Manchester Geol. Soc. vol. i. (1841) p. 194.

quarried at Glyn Ceiriog and elsewhere. He correlates the lower part of the series with the Wenlock, and the upper part with the Ludlow of Murchison, and considers the rocks of Dinas Bran to represent the Upper Ludlow. In this he is probably more nearly correct than is generally admitted.

Sedgwick, in his various writings, refers several times to the Denbighshire series of the Llangollen area, and in his description of a section drawn from Llansaintffraid Glyn Ceiriog to Cyrn-y-brain [1] he describes the succession in some detail. In the 'Upper Silurian' he recognizes a lower zone of roofing-slate with *Graptolites ludensis*, and above this a great thickness of Denbighshire Flagstone. The latter he divides into lower and middle divisions, with *Creseis* [*Orthoceras*] and *Graptolites ludensis*, and an upper division—the rocks of Dinas Bran—with *Terebratula* [*Dayia*] *navicula*, etc. Except for the fact that several species of graptolites are confounded under the same name, this description, so far as it goes, gives a good idea of the succession. Sedgwick makes no attempt to correlate these subdivisions with those of the Silurian elsewhere, but dissents from the views expressed by Bowman on this subject.

A few years later an account of the geology of North Wales was published by Daniel Sharpe.[2] In the part of this paper which treats of the Llangollen district, Sharpe agrees in general with Bowman, and places a part of the Denbighshire series in the Wenlock and a part in the Ludlow. There is a certain amount of confusion in this paper as to the base of the Wenlock; but the author seems to be inclined to draw the boundary between his Wenlock and 'Lower Silurian' below the flags [Nantglyn Flags] and above the zone of roofing-slate [Pen-y-glog Slates].

The account of the Denbighshire series which is given in the Geological Survey Memoir on North Wales [3] is very short, and no serious attempt is made to describe the succession. The whole is placed provisionally in the Wenlock, but it is pointed out that the upper part may possibly belong to the Ludlow. In the palæontological appendix the beds of Castell Dinas Bran and the Llansannan shales [4] are separated from the rest as a higher subdivision.

Beyond a few casual references, nothing further seems to have been written concerning this area until 1880, when a paper appeared by Mr. J. E. Marr [5] on the geology of the Dee Valley. In this Mr. Marr describes the Pen-y-glog Slates, at the base of the series; the Pen-y-glog Grits above them; and the Dinas Bran Beds, which he places at the top of the Silurian of this area. He correlates the whole series with the Brathay Flags and Coldwell Beds of the Lake District and with the Wenlock of Murchison.

In an announcement of the discovery of remains of plants at the

[1] Proc. Geol. Soc. vol. iv. (1843) p. 263.
[2] Quart. Journ. Geol. Soc. vol. ii. (1846) p. 283.
[3] Mem. Geol. Surv. vol. iii. ed. 2 (1881), pp. 284, 300.
[4] Prof. Hughes suspects that the Llansannan shales lie at a much lower horizon than the top of the Denbigh grits, Proc. Chester Soc. Nat. Sci. & Lit. pt. iv. (1893) p. 150.
[5] Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 277.

base of the Denbighshire Grits near Corwen, Dr. H. Hicks [1] gives a section across our area. He refers the Pen-y-glog Slates and apparently the gritty beds above them to the Upper Llandovery, and places in the Wenlock only the higher slaty beds above the grits—in his section the slates of Moel Morfydd. The graptolitic fauna of the Pen-y-glog Slates and their position above the Tarannon Shales are sufficient to show that this correlation cannot be accepted in full.

[Since this paper was read, my attention has been drawn to the account of the geology of North Wales given by Dr. Hicks in the 'Explication des Excursions' of the International Geological Congress at London in 1888, in which he states that the upper beds of the North Welsh Silurian, visible at Dinas Bran and Moel Morfydd, may probably be referred to the Ludlow.[2]—Nov. 22nd, 1894.]

There are no further notices to record; and it will thus be apparent that the Denbighshire series of this area has received but scanty attention from geologists, and that little has been added to the old descriptions of Bowman and Sedgwick. Farther north, however, in the Vale of Clwyd, the series has been examined in detail by Prof. Hughes.[3] He recognizes the Pen-y-glog Slate and the Pen-y-glog Grit, already noticed in the Dee Valley. The grit is succeeded by a great thickness of flags which he calls the Nantglyn Flags, and which are characterized by Orthoceratites, *Actinocrinus*, etc.; and these are followed by a series of more gritty beds, in one subdivision of which he finds *Acidaspis Hughesi*, Salter, MS. This species occurs in the Coniston Grits of the Lake District, but is also recorded from other horizons. Prof. Hughes refers a part of the upper gritty beds of the Clwyd to the Ludlow, and the beds below to the Wenlock. It will be seen subsequently that the correspondence between this succession and that of the Dee Valley is extremely close.

III. Description of the Area.

The Denbighshire series of the southern part of Denbighshire forms an incomplete basin which lies between the Bala rocks of Cyrn-y-brain on the north and those of the Berwyns on the south, and which extends from the Nant Morwynion fault on the west till it is covered in the east by the Carboniferous rocks of the North Wales coal-field. In the portion of this basin which lies north of the Dee the beds are greatly folded and cut up by faults; but in the part which lies south of that river, the faults are few, and the dip of the beds is low and very regular. It is the western portion of this southern half which will now be described. Here the rocks are comparatively well exposed, and the sequence can be determined without much difficulty.

[1] Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 482.

[2] Congr. Géol. Intern. 4me Sess., Compte-rendu, London, 1888, p. 286.

[3] Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 694; Proc. Chester Soc. Nat. Sci. & Lit. no. 3 (1885) p. 8, pt. iv. (1893) p. 141.

To define the area a little more exactly, it extends from the Holyhead road on the north to the Tarannon Shales on the south, and from the ridge of Moel-y-Gwynt on the west to the wooded spur sometimes known as Wriddiog [1] on the east. In the western part of the area a fault which runs a little north of east separates this part of the basin from the more disturbed portion north of the Dee.

Throughout the greater part of this area the dip is between north and east at a low angle; but near the road it is frequently horizontal or a little south of east, showing that we may place the axis of the basin nearly along the line of the road. A little way north of the Dee at Glyndyfrdwy the dip becomes southerly, and it is also southerly in the southern part of Wriddiog. Farther north we get into the disturbed region of the northern half of the basin.

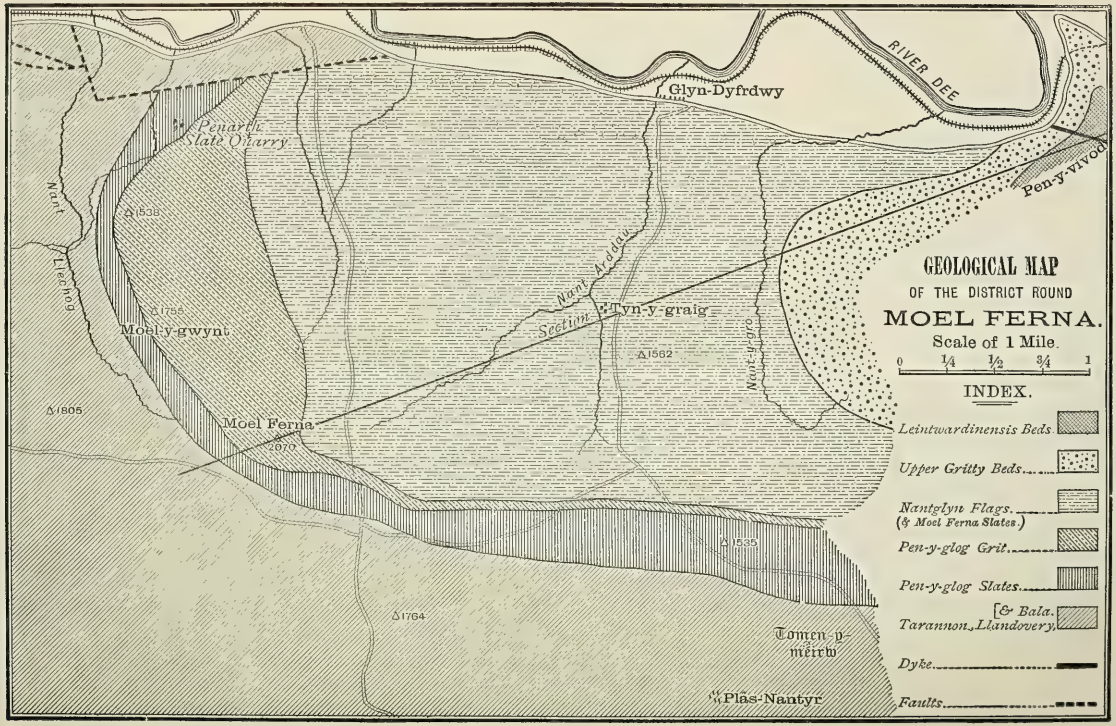
Physically, the area described may be considered as a somewhat irregular plateau in which deep valleys of northerly direction have been cut, leaving in the southern part a ridge stretching from east to west, which forms the watershed between the Dee and the Ceiriog. The culminating point of this ridge is Moel Ferna, at its western extremity, the summit of which rises to a height of 2070 feet above the sea. From this two spurs project towards the Dee: to the north is Moel-y-Gwynt, which runs towards Carrog and overlooks on the west the flat and heather-covered valley of the upper part of Nant Llechog; to the north-east a prominent spur stretches as far as Glyndyfrdwy, but unfortunately bears few exposures. Farther east the watershed throws out spurs which range due north: a small one between the main and tributary branches of Nant Arddau; a second and larger one between Nant Arddau and Nant-y-gro; and a third, still larger, east of Nant-y-gro. This third ridge, as it nears the Dee, bends round and runs towards the east, forming the steep and striking slope on the southern side of the Holyhead road about two miles east of Glyndyfrdwy. The wooded spur Wriddiog is physiographically a continuation of this ridge, once more bent round so as to run towards the north.

IV. The General Sequence.

At the northern end of the spur which runs north from Moel Ferna the pale shales of the Tarannon series are succeeded by dark banded slates,[2] which have been extensively worked at the Penarth quarries of Pen-y-glog near Carrog. They have been already frequently described, and contain *Monograptus personatus*, *M. priodon*, *Retiolites Geinitzianus*, etc.

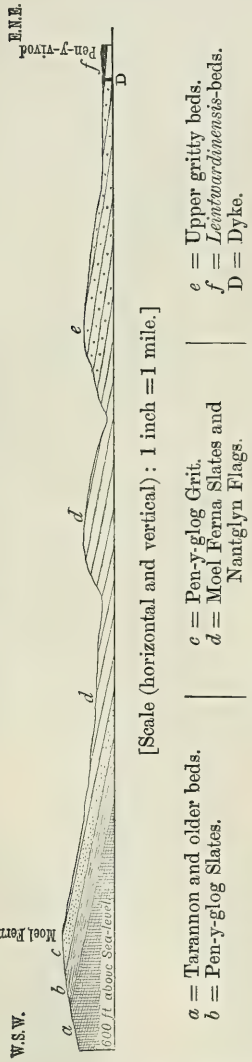
[1] This is unnamed in the New Series of 1-inch Ordnance maps. It is the spur which projects into the V-shaped bend in the Holyhead road shown on the map.

[2] These slates are usually known in geological literature as the Pen-y-glog Slates, from the name given to the hill on the old Ordnance maps. The name 'Pen-y-glog' is, however, almost unknown in the district; and the quarries, which are now no longer worked, were called the Penarth slate-quarries.


RIVER DEE
Glyn-Dyfrdwy
Penarth Slate Quarry
Nant Llechog
△1538
△1755
Moel-y-gwynt
△1805
Moel Ferna
2070
Nant Arddau
Section
Tyn-y-graig
△1562
Nant-y-gro
Pen-y-vivod
△1535
△1764
Tomen-y-meirw
Plas-Nantyr
GEOLOGICAL MAP
OF THE DISTRICT ROUND
MOEL FERNA.
Scale of 1 Mile.
0 1/4 1/2 3/4 1
INDEX.
Leintwardinensis Beds
Upper Gritty Beds
Nantglyn Flags.
(& Moel Ferna Slates.)
Pen-y-glog Grit.
Pen-y-glog Slates.
Tarannon, Llandovery. [& Bala.
Dyke.
Faults.

These slates are followed by a grit, which forms the upper part of the quarry, and which may be traced southward along the ridge of Moel-y-Gwynt to the top of Moel Ferna. There it bends round eastward and forms the crest of the watershed between the Dee and the Ceiriog until it is lost in the heather, which covers everything east of the road from Glyndyfrdwy to Nantyr. No doubt it still continues under the heather, probably in a somewhat attenuated form, for a grit appears in the same stratigraphical position a few miles farther east, a little way north of Llansaintffraid Glyn Ceiriog.

Section from Moel Ferna to Pen-y-vivod.



[Scale (horizontal and vertical): 1 inch = 1 mile.]

a = Tarannon and older beds.
b = Pen-y-glog Slates.
c = Pen-y-glog Grit.
d = Moel Ferna Slates and Nantglyn Flags.
e = Upper gritty beds.
f = *Leintwardinensis*-beds.
D = Dyke.

On Moel Ferna the grit dips beneath slates, which are exposed a very short distance east of the summit and lower down on the eastern flanks of the hill are worked in the quarries known as the Moel Ferna slate-quarries. They closely resemble the Pen-y-glog Slates, consisting of well-cleaved dark banded slates; but graptolites are not so abundant. The only forms found here were *Monograptus priodon* and *M. Flemingi*.

Proceeding down the valley of Nant Arddau these slates are succeeded by the well-known flags of the Denbighshire series, which are so frequently quarried, and to which Prof. Hughes has given the name of Nantglyn Flags. They are dark in colour, with numerous very thin, pale-coloured, gritty, or siliceous bands, and they usually split along the bedding. In this valley they are extensively worked at the Deeside slab-quarries, on the flanks of a prominent hill immediately south of the stream. Here, as elsewhere, the commonest fossils are *Orthoceras primævum*, Forbes, *O. Sedgwicki*, Forbes, *O. ventricosum*, Sharpe, and—most important of all—*Monograptus colonus*, Barr.

The flags cover a very extensive area, and the characteristic fossils may be found in many places. Continuing our section towards the east, they form the whole, except perhaps the top, of the hill between Nant Arddau and Nant-y-gro. They also occur along the western

and northern foot of the hill east of Nant-y-gro, and are then followed by a considerable thickness of much more siliceous beds, in which no fossils have yet been discovered.

These siliceous or gritty beds form the whole of the top of this hill and dip gently to the east, occupying most of the steep slope south of the Holyhead road. As we approach Pen-y-vivod they pass up into less gritty and more slaty beds; but no very definite boundary can be drawn between the two series.

On the Wriddiog spur, where the Holyhead road makes an acute-angled V, what appear to be the same gritty beds are well exposed. They here form an anticlinal or part of an elliptical dome, and on the southern side of this anticlinal they are shown in a quarry by the side of the road, where they dip 37° E. of S. at an angle of 15°. Following the path which leads from the road up the side of Wriddiog to Pen-y-vivod they are succeeded by more slaty beds which split up into long prisms, and in which *Monograptus leintwardinensis* occurs in large numbers. Between these *Leintwardinensis*-beds and the slaty beds close to Pen-y-vivod runs a small dyke,[1] which has been worked apparently under the impression that it was a mineral lode. There is no evidence of a fault along the line of this dyke, and therefore, though *Monograptus leintwardinensis* has not yet been found south of the dyke, it must be concluded that the slaty beds near Pen-y-vivod belong to the same horizon. They certainly overlie gritty beds of much the same character as those of Wriddiog.

It is clear, then, that the Denbighshire series, so far as it is seen in this part of the basin, may be divided, in descending order, into:—

Slaty beds with *Monograptus leintwardinensis*.
Gritty beds.
Flags with *M. colonus, Cardiola interrupta, Orthoceras primævum*, etc.
Moel Ferna Slates, with *M. Flemingi, M. priodon*.
Pen-y-glog Grit.
Pen-y-glog Slates, with *M. personatus, M. priodon*, etc.

Dinas Bran Beds.

The *Leintwardinensis*-beds are the highest in the area described in the present paper, but higher beds than these occur within the basin. East of Wriddiog there is a certain amount of disturbance and a small fault, so that the sequence is no longer quite continuous and requires further examination. But the disturbance is not great; the rocks are of the same character on the two sides of the fault, and the discontinuity must be small. The general dip, as is well shown in the bed of the Dee, is easterly, and the beds near Llangollen must therefore lie above the *Leintwardinensis*-slates. The most interesting of them are those of Dinas Bran, the striking conical hill north-east of that town. These have already been

[1] Fragments of what appears to be the same dyke are to be found on the hill immediately north of the Dee at Glyndyfrdwy, in the little valley which runs up from Coed-ial.

noticed by several geologists since the time of Bowman, and contain many fossils. They will be again referred to, and the only point which it is necessary to notice at present is that they appear to be considerably higher in the series than the *Leintwardinensis*-beds.

V. Detailed Description of the Beds.

Now that the order of succession among these rocks has been established, it will be possible to enter into more detail concerning the character of the subdivisions and of their included fossils.

Pen-y-glog Slates.

The lowest beds of the Pen-y-glog Slates are seen in some heaps of débris which lie immediately west of the main waste-heaps of the Penarth slate-quarry. They are very shaly in character and very deeply weathered, presenting a dull and earthy appearance. Occasionally a piece may be found which is not weathered quite to the centre, and then it appears that the original colour was a dark blue, not unlike that of the higher beds of these slates. Graptolites are common and well-preserved, the following species occurring:—*Monograptus priodon*, Bronn, *M. personatus*, Tullb., *M. vomerinus*, Nich., *Retiolites Geinitzianus*, Barr., and *Cyrtograptus Murchisoni*?, Carr.[1]

The same slates are exposed in the stream which runs a little east of Tomen-y-meirw[2]; and here their relations to the Tarannon Shales are clearly seen in a little gorge north of the Glyndyfrdwy and Glyn Ceiriog road. There is a gradual passage, and the dark shales are interbedded with the pale shales of the Tarannon along the boundary-line. I did not, however, succeed in finding the characteristic graptolites, probably owing to the dampness of the rocks.

Outside our area, but within the Llangollen basin, the same slates are well exposed on the western side of Caer Drewyn, near Corwen, and on the eastern flanks of Moel-y-faen, by the side of the direct road from Llangollen to Ruthin through Pentredwfr, about 1 mile north of Pentredwfr. In both places they lie immediately above the Tarannon Shales; in both places, too, they contain *Monograptus personatus* and *Retiolites Geinitzianus*, and present the deeply weathered appearance characteristic of them at Pen-y-glog.

The slates of the Penarth quarry itself, which lie above these, are well cleaved, dark banded slates which occasionally contain pyrites and bands of anthracite. The fossils which have been found in them are the following[3]:—

[1] These forms were collected by Mr. T. T. Groom and myself, and were kindly named for us by Mr. J. E. Marr.

[2] This is an ancient tumulus, 3 miles south of Glyndyfrdwy, and about 2½ miles due west of Llansaintffraid Glyn Ceiriog.

[3] This list is based on a list of graptolites collected by Dr. Hicks and named by Prof. Lapworth (Quart. Journ. Geol. Soc. vol. xxxvii. 1881, p. 488, footnote); on Marr (*op. cit.* vol. xxxvi. 1880, p. 283); on Hicks (*op. cit.*

Monograptus vomerinus, Nich.
„ *personatus*, Tullb.
„ *priodon*, Bronn.
„ „ var. *riccartonensis*, Lapw.
„ „ var. *Flemingi*, Salt.
Retiolites Geinitzianus, Barr.
Cyrtograptus Murchisoni, Carr.
Acroculia haliotis, Sow.
Orthoceras Sedgwicki, Forbes.
Orthoceras, sp.
Berwynia Carruthersi, Hicks.

—together with fragments of encrinites and brachiopods.

These slates are but little exposed in our area. There is a small quarry in them a little south of the road from Glyndyfrdwy to Glyn Ceiriog, about 1 mile north-west of Tomen-y-meirw. They form, however, a widely-spread zone, and it will be sufficient to refer to Caer Drewyn and Glyn Ceiriog as localities where they may be studied in the Llangollen basin.

Pen-y-glog Grit.

This is well seen in the Penarth quarry, of which it forms the top. It is generally a coarse felspathic grit, with narrow partings of soft and shaly beds. Its thickness is not great, but, owing to the fact that the dip nearly coincides with the slope of the ground south of the quarry, it covers a wide area on the ridge of Moel-y-Gwynt. It can be traced continuously to the summit of Moel Ferna, and thence eastward for a distance of about 1 mile. Farther east it is lost in the heather, and no satisfactory exposures are to be found until we approach Llansaintffraid Glyn Ceiriog. It appears to become thinner, or at least not so strongly marked, in this direction, and no longer forms the prominent feature which it does on Moel Ferna and Moel-y-Gwynt.

Fossils are not uncommon. At Pen-y-glog Dr. Hicks obtained remains of plants which have been referred to *Nematophycus* (*N. Hicksii*, R. Eth.) and *Pachytheca*, and also spores of what appears to be a lycopodiaceous plant. On the ridge of Moel-y-Gwynt and on Moel Ferna fragments of graptolites and brachiopods occur.

In the Woodwardian Museum the following fossils are recorded from the grit of Caer Drewyn, near Corwen, which is the northerly continuation of the Pen-y-glog Grit:—*Meristella tumida*, *Strophomena depressa* [*Leptæna* (*Strophomena*) *rhomboidalis*], *Phacops*, encrinite-stems, *Petraia* [*Lindstrœmia*] *duplicata*, var. *uniserialis*, and *Favosites fibrosa* (?).

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vol. xxxviii. 1882, p. 97); on specimens collected by myself; and on specimens in the Woodwardian Museum. It may be remarked that *Orthoceras Sedgwicki*, Forbes, is sometimes (but, I think, incorrectly) looked upon as a synonym of *O. subundulatum*, Portl.

Moel Ferna Slates.

It is only on Moel Ferna itself, where they have been quarried, that these slates can be recognized as distinct from the overlying flags. In character they are precisely similar to those of the Penarth quarry; but fossils are very rare. It was only in one or two blocks in the waste-heaps that I was able to obtain *Monograptus priodon*, Bronn, and *M. Flemingi*, Salter.

Judging from the character of the rock and the rarity of fossils, it seems possible that the slates of Moel-y-Faen, 4 miles north of Llangollen, lie on the same horizon as these.

Nantglyn Flags.

The succeeding series, to which we may appropriately apply the term already employed by Prof. Hughes in the Vale of Clwyd, consists of a great thickness of flaggy beds, which are mainly dark in colour, but are streaked with numerous very fine, lighter-coloured, and more gritty bands. Usually they split in the direction of the bedding and form the flags from which the whole series takes its name; but when the cleavage is better developed they break up into rhomboidal fragments in which the streaked appearance is well seen.

At the Deeside slab-quarries, south of Nant Arddau, they have been worked on a large scale, and the following fossils occur:—

Orthoceras primævum, Forbes.	*Cardiola.*
„ *Sedgwicki*, Forbes.	'*Actinocrinus*' *pulcher*, M'Coy.
„ *ventricosum*, Sharpe.	*Monograptus colonus.*

The specimens of *Actinocrinus pulcher* are sometimes extremely fine. Large slabs are covered with complete casts of the whole animal, with all the minutest branchlets beautifully preserved.

These flags extend across the valley to the east, and form the whole, except perhaps the top, of the hill between Nant Arddau and Nant-y-gro; and here a very complete section may be seen along the road from Nantyr to Glyndyfrdwy. The lower beds are exposed at the head of the tributary valley immediately west of this hill, in an old quarry in which characteristic Orthoceratites occur. On the side of the hill a little above this, *M. colonus* occurs in the débris of a trial-working; and immediately above, along the Nantyr road itself, the flags are well exposed. They consist of slaty beds with thin, hard, siliceous bands. Here and there the siliceous bands become more numerous, and at one point there is a bed of platy grit which is at least 20 feet thick. The dip is between north and east, and becomes more easterly as we proceed towards the north; but in general the beds dip in the direction of the road at a higher angle than the road itself, and thus the road cuts into higher and higher beds of the series, as it slopes down the hill from south to north.

All along the road, from a little north of the watershed to a point east of the farm of Ty'n-y-graig, *Monograptus colonus* occurs at

intervals, together with fragments of crinoids. It is as a rule most easily found in the gritty bands, especially on their under surfaces. Farther north, opposite Pandy, I obtained *M. Nilssoni*, and near the head of the incline at the village *Beyrichia Kloedeni*, *Chonetes minima*, encrinite-stems, and an indeterminable graptolite.

The top of this hill is formed in part of a different material. The slates are there pale, and a pale-coloured grit occurs: it is probable that these belong to the gritty series above the flags rather than to the Nantglyn Flags themselves.

Farther east the Nantglyn Flags form the lower part of the western and northern faces of the hill east of Nant-y-gro, and *M. colonus* occurs here also.

The following is the list of fossils found in the Nantglyn Flags in this area:—

Orthoceras primævum, Forbes.
„ *Sedgwicki*, Forbes.
„ *ventricosum*, Sharpe.
Cardiola.
Chonetes minima, Sow.
Beyrichia Kloedeni, M'Coy.
'*Actinocrinus*' *pulcher*, M'Coy.
Monograptus colonus, Barr.

Upper Gritty Beds.

Concerning these there is but little to say, as no fossils have yet been found in them. On the hill east of Nant-y-gro the *M. colonus*-beds are succeeded by a series of alternations of slaty and siliceous beds, which form the upper part of the hill, but are there mostly concealed by the heather. They dip at a low angle towards the east under the somewhat less gritty beds of the next division; and reappear with a more southerly dip in the road-metal quarry at the side of the Holyhead road in Wriddiog. Here they are very compact and dark blue in colour, banded with numerous regular pale-coloured siliceous bands an inch or two in thickness. There is a peculiar thin bed here which breaks up with the greatest ease into thousands of small cubical or rectangular blocks.

It should be noticed that the hard siliceous bands in this series are generally compact and fine-grained; so that in strictness perhaps the term 'grit' ought not to be applied to them.

Leintwardinensis-Beds.

These are found near Pen-y-vivod at the southern end of Wriddiog. In general appearance they are not unlike the Nantglyn Flags and are streaked with narrow bands of fine grit; but the surfaces of these bands present a characteristic glistening appearance due to small scales of mica, and this generally serves to distinguish them from any of the beds below. Another peculiarity which these beds have is that they break up into very long, narrow, prismatic blocks.

At the side of the path from Pen-y-vivod, a little north of the dyke already mentioned, there is an exposure of these rocks in which *Monograptus leintwardinensis*, Lapw., occurs abundantly; and *Orthoceras* and *Chonetes minima* have also been found.

Dinas Bran Beds.

Although they do not occur in our area, it may be well, in order to complete the account of the succession in the Llangollen basin, to give a list of the fossils which have been found on Dinas Bran. The beds which occur there are more sandy than the rest of the series, and break up into irregular prisms. The following list is drawn from Mr. Marr's paper, with a few additions :—

Spongarium Edwardsi, Murch.
Serpulites dispar, Salt.
Favosites fibrosus, Goldf.
'*Actinocrinus*' *pulcher*, M'Coy.
Ceratiocaris stygia, Salter.
Chonetes minima, Sow.[1]
Dayia navicula, Sow.
Rhynchonella nucula, Sow.
Ambonychia acuticostata, M'Coy.
Cucullella coarctata, Phill.
Ctenodonta.
Bellerophon expansus, Sow.[1]
Theca Forbesi, Sharpe.
Holopella gracilior, M'Coy.
Orthoceras Sedgwicki, Forbes.[2]
—— *laqueatum*, Hall.
—— *ibex*, Sow.
Calymene.

VI. Correlation with other Areas.

Vale of Clwyd.[3]

The lower part of the Denbighshire series in the Clwyd valley corresponds so exactly with that in the Vale of Llangollen that the same description will apply to both, and it is quite unnecessary here to enter into further details. It is in the upper part of the series only that no precise correlation can be attempted. *Acidaspis Hughesi* has not been found in the Dee Valley ; and on the other hand the zone of *Monograptus leintwardinensis* is unknown in the Vale of Clwyd, nor does it appear—since the Llansannan Shales are not to be correlated with them—that anything precisely corresponding with the Dinas Bran Beds has yet been recognized in North Denbighshire. These points require further examination ; for at least there can be little doubt that both *Acidaspis Hughesi* and *Monograptus leintwardinensis* will be found to occur in both areas.

The Long Mountain.

Outside of Denbighshire itself, the region which resembles the Vale of Llangollen most closely in its geology is the Long Mountain, which has been briefly described by Mr. Watts.[4] The sequence which he establishes corresponds very precisely with that in our area. Above the May Hill Grit come purple and green shales with few fossils, which agree on the whole with the grey slates and greenish Tarannon Shales which overlie the Corwen Grit in South Denbighshire. They appear, however, to extend somewhat higher up the series, for the succeeding 'Wenlock mudstones' contain *Cyrtograptus Linnarssoni*, *Monograptus Flemingi*, *M. dubius*, etc.,

[1] These specimens were collected by Miss Crosfield and Miss Elles, of Newnham College, Cambridge, and are now in the Woodwardian Museum.
[2] This is the *Orthoceras tenuicinctum*, Portl., of M'Coy's (Brit. Pal. Foss. p. 359) and Marr's lists.
[3] Hughes, Proc. Chester Soc. Nat. Sci. & Lit. pt. iv. (1893) p. 141.
[4] Rep. Brit. Assoc. (Leeds), 1890, p. 817.

and correspond with the Pen-y-glog Grit and Moel Ferna Slates rather than with the Pen-y-glog Slates themselves. These mudstones are followed by thin muddy shales with rare flaggy ribs, which contain *Monograptus colonus*, *M. Nilssoni*, and *Cardiola interrupta*, and which therefore represent the Nantglyn Flags. They are succeeded by hard, thick flags with shales, in which *Monograptus leintwardinensis*, *M. Salweyi*, and *M. Roemeri* occur; and these must be the equivalents of the *Leintwardinensis*-beds of Pen-y-vivod. The upper beds of the Silurian in the Long Mountain are almost barren, so that we can say no more than that they are the representatives of the beds above the *Leintwardinensis*-zone.

Welsh Borders (Central and Southern).

In the typical Silurian area the Wenlock Shales contain *Monograptus priodon* and other graptolites of the Pen-y-glog Slates. The Lower Ludlow Shales contain *M. colonus* and *Cardiola interrupta* like the Nantglyn Flags; and hence we may probably place the Pen-y-glog Grit and Moel Ferna Slates between these two, at about the horizon of the Wenlock Limestone.

The Leintwardine Flags with *Monograptus leintwardinensis* clearly correspond with the *Leintwardinensis*-beds of the Llangollen basin, and the Dinas Bran Beds must therefore be of Upper Ludlow age.

Lake District.[1]

In the Lake District, as has already been pointed out by Prof. Hughes and Mr. Marr, the succession is remarkably like that in Denbighshire. The Brathay Flags with *Monograptus priodon*, etc. correspond exactly with the Pen-y-glog Slates. They are followed by the Lower Coldwell Beds, which are coarse, grey, unfossiliferous grits, and no doubt represent the Pen-y-glog Grit. These are succeeded by the Middle Coldwell Beds, which are calcareous, flaggy grits, with a tolerably abundant fauna. No precise representative of them is to be found in Denbighshire; but from their position they probably correspond, in part at least, with the Pen-y-glog Grit and Moel Ferna Slates. The next subdivision, the Upper Coldwell Beds, consists of gritty flags of great thickness, in which *Monograptus colonus*, *Actinocrinus pulcher*, *Orthoceras primævum*, etc. occur: both lithologically and palæontologically they therefore resemble the Nantglyn Flags.

The Upper Coldwell Beds are succeeded by the Coniston Grits, which are generally unfossiliferous. Prof. Hughes describes a band which contains *Acidaspis Hughesi* in abundance; and he finds a similar band in the grits above the Nantglyn Flags of the Vale of Clwyd. This species, however, in the Lake District at least, is not confined to one horizon. In the Llangollen basin, although the

[1] See Marr, Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 871; Geol. Mag 1892, p. 534.

Upper Gritty Beds have yielded no fossils, it is clear from their position that they correspond with the Coniston Grits.

Above the Coniston Grits come the Bannisdale Slates, in which Mr. Marr has obtained *Monograptus leintwardinensis*, *M. Salweyi*, etc., and these must therefore correspond in part with the *Leintwardinensis*-beds of Pen-y-vivod.

It is not easy to determine precisely what part of the Lake District sequence corresponds with the Dinas Bran Beds. The abundance of *Dayia navicula* in the latter might suggest that they represent the passage-beds between the Bannisdale Slates and the Kirkby Moor Flags; but this species is not by any means limited to that horizon. The position of the Dinas Bran Beds, however, forces us to place them either at the top of the Bannisdale Slates or in the Kirkby Moor Flags; and the fossil evidence certainly does not oppose this view.

Approximative Correlation of the Wenlock and Ludlow Rocks on the Welsh Borders, in North Wales, and in the Lake District.

	Welsh Borders.	North Wales.	Lake District.
Clunian.	Downton Sandstone.		
	Upper Ludlow Shales.	Dinas Bran Beds.	Kirkby Moor Flags.
	Aymestry Limestone.		Bannisdale Slates.
	Leintwardine Flags.	*Leintwardinensis*-beds.	
Salopian.	Lower Ludlow Shales.	Upper gritty Beds.	Coniston Grits.
	Wenlock Limestone.	Nantglyn Flags. Moel Ferna Slates and Pen-y-glog Grit	Upper, Middle, Lower } Coldwell Beds.
	Wenlock Shale.	Pen-y-glog Slates.	Brathay Flags.

VII. Conclusion.

It will be clear, upon the face of the foregoing evidence, that the Denbighshire series is by no means the abnormal development of the Silurian which it is sometimes represented to be; but that, on the other hand, it belongs to the most widely-spread facies of that system in England. The beds of limestone, with their peculiar faunas, which occur in the Silurian of the Welsh borders, are not found in North Wales and the Lake District; but if these be left out of consideration, the sequence is very similar in the three areas.

Moreover, the Denbighshire series does not correspond with the Wenlock only, as is frequently stated. It contains representatives of the Ludlow, and indeed of the Upper Ludlow. It is only the uppermost beds of the latter which appear to be absent.

Discussion.

Prof. Hughes remarked that, although the broad features of the Silurian rocks had long ago been sketched out, there was much to be done in working out the zones in those great masses of stratified rock, each division of which was as large as the whole of the Secondary or Tertiary system. Towards this work Mr. Lake's paper was a valuable contribution, and, from his knowledge of that area and of similar sequences elsewhere, he could only confirm Mr. Lake's general conclusions.

Mr. Hopkinson said that he could corroborate, from his own investigation of the Ludlow rocks in the vicinity of Ludlow, Mr. Lake's correlation of the beds he had described with those of the typical Upper Silurian region. In the Wenlock Shale near Burrington were such forms as *Monograptus priodon* and *Cyrtograptus Murchisoni*; in the Lower Ludlow mudstones just above the Wenlock Limestone at Wigmore, etc., *M. colonus* occurred in abundance, becoming less numerous as some half-dozen other species of *Monograptus* gradually came in; and just below the Aymestry Limestone around Leintwardine and elsewhere, *M. leintwardinensis* suddenly appeared in swarms. In a bed of shale intercalated in the Aymestry Limestone at Bow Bridge near Downton was a peculiar group of dendroid graptolites unknown elsewhere. He had not detected a single graptolite in the Upper Ludlow rocks in this area.

Dr. H. Hicks said that he had communicated two papers to the Society on some of the beds referred to in this paper; but they dealt chiefly with the plant-remains in the Pen-y-glog quarry. This paper by Mr. Lake entered far more fully into the subdivisions above the Pen-y-glog Beds; and he looked upon the discovery of *Monograptus leintwardinensis* as of much importance, and as proving clearly that the higher beds of Dinas Bran must be of Upper Ludlow age.

Mr. Marr congratulated the Author on the completion of a very careful piece of work. He remarked that *Monograptus colonus* would be doubtless found to range above the Nantglyn Flags into the *Leintwardinensis*-beds. Dr. Hicks had many years ago announced to the speaker that he considered that certain beds in the Llangollen district were Ludlow, and had exhibited fossils which undoubtedly corroborated his opinion, but the credit of dividing these beds into zones belonged to the Author.

Mr. Watts pointed out that the identification of Ludlow rocks in the Long Mountain was originally due to Aveline's mapping for the Geological Survey, although the line there adopted was not quite the same as that indicated by palæontological evidence. Probably the grits below the *Leintwardinensis*-slates were also present in the Long Mountain.

The Author remarked that he had not found *Monograptus colonus* and *M. leintwardinensis* together in this region; but he should be inclined to suspect that they might occur together in the beds below the Pen-y-vivod Slates rather than in the Pen-y-vivod Slates themselves.

3. Supplementary Note *on the* Narborough District (Leicestershire). By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read December 5th, 1894.)

The outcrops of crystalline rock in the Narborough district were described, in 1878, by the Rev. Edwin Hill and myself in the second of our papers on Charnwood Forest.[1] Since that time the old quarries have been much enlarged and others have been opened. These, one hoped, might have disclosed some new facts, and increased experience might occasionally suggest a different interpretation of things already seen. Hence I became anxious to pay a parting visit to the district before it passed, so to say, into other hands, and spent two or three days there in the Easter holidays of 1893,[2] without, however, the advantage of my friend's companionship, for just at that time he was unable to leave home.

On our former visits we had not succeeded in finding either any dykes cutting the crystalline masses,[3] or more than one junction between the latter and the sedimentary rocks of the Forest series. I had hoped that in the process of quarrying some of the one and more cases of the other might have been discovered. But I was disappointed in both respects, though additional information was obtained as to the junction already known in the neighbourhood of Enderby. Some of the pits also afforded rather interesting sections of Boulder Clay. There is, however, so little to record[4] that the fact of our former papers having appeared in this Journal alone emboldens me to submit this supplementary note to the Society.

The quarries near the villages of Enderby, Croft, Huncote, Stony Stanton, and Sapcote, though now more numerous and often greatly enlarged, furnished nothing new of any importance. In a disused pit nearly south of the windmill at Stanton Fields, near Sapcote, I observed on the quarried face one or two patches of a darker coloured rock, 2 or 3 inches in diameter, which probably were nodes, and was shown by the manager of a pit, north of the

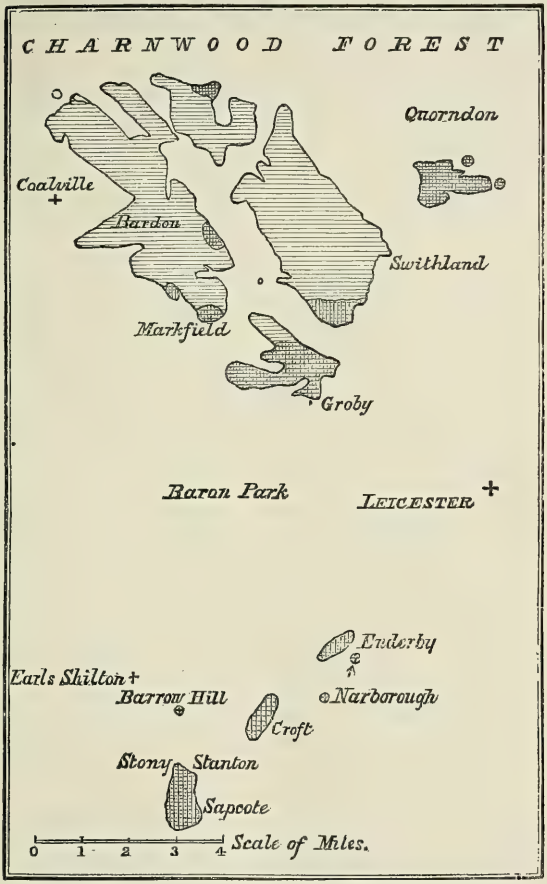
[1] Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 225.

[2] After writing this paper, I visited some of the places near Narborough (in September last) and found that a pit had been opened in a new locality, as described in the text.

[3] Dykes in the hornblendic granite and the 'syenite' of Charnwood Forest are described by us, *op. cit.* pp. 220–224.

[4] The increased size and especially depth of the pits, and the amount of work which is carried on, make it almost impossible to examine some of them. When the bottom of a pit was practically inaccessible, I walked round the edge, examined the stone brought up, and made enquiries from foreman or manager, as to whether the rock had been found to vary. I got no hint of the discovery of a dyke or of a new junction.

Sketch-map of the Charnwood and Narborough District.



[Horizontal shading shows slaty rocks, cross shading igneous rocks; precision of outline has not been attempted.]

Note: Huncote Pit is at the northern end of the Croft *massif*, the village bearing the latter name being at the southern end. The new pit is very slightly north of a line joining the Narborough *massif* with the north end of the Croft one, and rather nearer the former.

The arrow-head indicates the position of the pit which contains the junction of slate and syenite, near Enderby; the village is on the larger outcrop, the quarries being near the middle of it.

high road and a little nearer the village, specimens resembling the coarse granitoid rock, sent to us, as mentioned in our third paper, by Mr. W. J. Harrison.[1] It appears to occur in either the ordinary rock or a slightly darker variety of it, more like a node than an included fragment, for the boundary is not quite sharp, and it forms masses sometimes measuring 2 or 3 cubic feet.

As my descriptions in 1878 were made from a small number of slices, I have now had more specimens prepared.[2] At Enderby village I have examined the rock of 'Rawson's Pit' and that of the 'Enderby Company' lower down the hill on the north; at Stony Stanton I have slices from pits, one north of the village and another south-east of it; in the Sapcote *massif* (doubtless part of the same) from an old pit, north of the road on the east side of Sapcote village, and at Croft Hill, from the pit at the southern end. All these show the same general characteristics with those described in the former paper (excepting, of course, the specimens from the Lower Enderby and the Narborough quarries). The differences between them are so slight and unimportant that any minute descriptions are not worth printing. Here a porphyritic structure may be slightly more distinct; there the groundmass may contain a little more or a little less quartz, or be a trifle coarser or finer in grain; sometimes the hornblende may be better preserved (the biotite is generally altered) or be more completely idiomorphic (as in the old pit near Sapcote) than at others. The groundmass consists of small prisms of felspar (decomposed and reddish, mostly, I think, orthoclase) with interstitial quartz.[3] The porphyritic felspars, commonly about ·05 to ·08 inch in diameter, are fairly idiomorphic; their state of preservation varies; they are usually plagioclase, often zoned, partly oligoclase, partly labradorite, so far as one can conclude from their extinction-angles. A yellowish mineral resembling sphene, probably arising from the decomposition of ilmenite, is sometimes present, also a little epidote. A colourless augite can be recognized in a specimen from Huncote, and the mineral may be present in others, but certainly is not now common. I have not identified any rhombic pyroxene.

The pit at Barrow Hill has been somewhat enlarged. I believe that, as suggested in the last paper, only one kind of rock is quarried here; the colour-change being mainly, if not wholly, due to weathering. The rock which crops out in a field roughly west of the windmill seems to me slightly more porphyritic than that in the pit on the opposite side of this building; while that in an old shallow working about 300 yards away to the south-east appears in places rather more compact and redder than either. I have examined it microscopically, but the difference from the earlier specimens is so slight as to be unimportant. The rock of Barrow Hill is certainly rather less quartzose than that of the other outcrops, and the

[1] Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 349.

[2] Altogether twenty-one slices.

[3] Apatite is not uncommon in some slices; iron oxide, generally black, occurs in small grains; a zircon is present in the Sapcote slide.

elongated form of the felspar in its groundmass suggests that this constituent is mainly plagioclase.

The quarry west of Narborough, near the Huncote road, has been much enlarged and deepened.[1] The stone which is now being raised appeared to me slightly coarser in grain and more porphyritic than it was at our last visit, so I have examined microscopically three more specimens; one, as an average sample; another, containing a dull green mineral in rather narrow prisms, about $\frac{1}{4}$ inch long; and a third which includes a darker node or fragment about 1 inch in diameter. They are very slightly coarser than the specimen already described, and quartz occurs as a porphyritic constituent as well as felspar, but in smaller grains, approximatively four times the diameter of those in the groundmass. The ferromagnesian constituent is ill-preserved; probably, as in the other slides, some biotite has been present as well as hornblende. But even the larger green crystals already mentioned consist of a mass of secondary products among many granules of iron oxide. Their shape, however, corresponds better with that of hornblende, and the mode of occurrence of the black grains suggests that, as is common in andesites and trachytes, they were separated from the original mineral at a stage in its history anterior to the final consolidation of the rock. The enclosure consists of lath-like felspar (decomposed) with a little interstitial quartz, rather more iron oxide (some being hæmatite) than in the surrounding rock, and about the same amount of the ferromagnesian constituent. This rock, which perhaps is an included fragment, on the whole resembles that of Barrow Hill more than any other in the neighbourhood.

About a furlong from the road to Huncote, and rather less than $\frac{1}{2}$ mile from the last-named pit, a new one was opened in September 1893. This is in a field on the right bank of a small stream. The excavation already has attained to a considerable size, and trial-openings have shown that the 'syenite' is within a short distance of the surface over an area perhaps half an acre in extent. The rock on the western side of the pit is covered by about 1 foot of soil, and I was told that in one place it had come still nearer the surface. It lay at a depth of about 5 feet on the north and 11 on the west, but towards the east it appeared to be shelving down more rapidly. In all these places it was overlain by Keuper Marl, and no true Boulder Clay was visible. The soil, at the time of my visit, had been stripped away, exposing a surface of the rock approaching 100 square yards in area. This was rather irregular, without any signs of glaciation, and not very much decomposed, the rock, within a few inches of the top, being in fairly good condition. Macroscopically it seemed a shade coarser than that of the pit nearer Narborough, but, after examining a section under the microscope, I am unable to discover any noteworthy difference between it and the specimens described in the preceding paragraph.

[1] To a depth of 60 or 70 feet from the surface, or about 50 feet into the 'syenite.'

The resemblance in the groundmass of the rock in the two pits between Narborough and Huncote and in that south of Enderby—this being granular instead of 'quasi-ophitic' and distinctly more minute in structure than in the other localities—is interesting, and suggests that the former pits also may be near the boundary of an intrusive mass.[1] It is also worth noting that the micrographic structure, so characteristic of the 'syenites' of the Forest district, is absent from these masses. An indication of it perhaps may be traced in one or two of the specimens, but this is so slight that I may venture to say that the structure is as characteristically absent here as it is present in the other district. This group of rocks evidently occupies an intermediate position between fine-grained varieties of syenite and diorite, inclining rather to the latter, and being sufficiently quartziferous to bring them near to the border of granites and tonalites.

More interesting results have followed from the enlargement of the quarry in the outcrop on the lower ground south-east of Enderby village.[2] The section formerly exposed at the south-eastern side of the pit is no longer visible, probably being concealed by débris, but new junctions have been disclosed by the advance of the quarry westwards. These were shown me by the manager, Mr. A. R. Marston, to whom I am indebted for giving me not only every facility for examining them, but also some valuable information. The 'slate,' he said, had proved to be wedge-like in plan, the axis running roughly W.N.W., and he thought that its extremity must have been almost reached.[3] The mass also was wedge-like in section, the northern slope being the steeper one. Hence it was enveloped, so far as could be seen, by the 'syenite.' I examined actual junctions of the two rocks (in 1893) and obtained specimens. In one place the syenite thrusts a short blunt tongue into the 'slate,' at another it slightly contorts the latter. This in one part is much indurated and almost 'flinty,' but it is generally somewhat fissile, the cleavage probably being anterior to the intrusion. I have examined under the microscope two specimens of the sedimentary rock, one showing an actual junction, the other from the flinty-looking variety, perhaps 2 or 3 feet from the intrusive mass. In the former the sedimentary part appears to be made up of specks of opacite and ferrite, tiny yellowish granules and minute flakes of mica, partly brownish to olive-tinted, partly colourless; the latter

[1] At present our information is hardly sufficient to serve as a basis for speculation, but we may anticipate that the area of buried crystalline rocks in this district is considerably larger than that marked by their outcrops, and that the slate may be looked for on the southern side of the pits between Narborough and Huncote.

[2] Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 227. In the second line of p. 228, *south* is miswritten or misprinted for *north* (better 'more northern').

[3] The appearances in 1893 suggested that he was right in this opinion. In 1894, however, though the pit had been carried some yards farther back, the end of the mass had not been reached. Still, so far as I could judge, it did not rise so high from the floor or cover so wide a space.

giving bright colours with crossed nicols. Here and there occur larger flakes of a pale olive-brown, somewhat dichroic mica, in clusters, with an approach to a vein-like arrangement. There are larger grains of opacite and ferrite, and streaks in which angular or subangular transparent grains, about ·001 inch in diameter or less, are fairly abundant; and occasionally slightly clear spots seem to be forming. In one or two places the former presence of fragments is suggested, but it is most difficult to explain the slight irregularities of structure exhibited by the rock. Partly, no doubt, they are due to original differences of composition, but partly they may result from incipient crystallization. The rock on the whole presents a certain resemblance to the slate at Brazil Wood, about 30 yards from the granite.[1] The igneous rock, a small portion of which (though it is rather rotten) has been retained in the slice, shows a perfectly welded, rather wavy surface. In the groundmass, rather ferrite-stained, perhaps once a glass, are felspar-crystals (replaced by secondary products) from ·02 inch in diameter downwards (the shape being more suggestive of orthoclase) with small quartzes, from about ·002 to ·003 inch in diameter, rounded in form, but exhibiting sometimes one or two angles of 120°. With these are grains of iron oxide and flakes of altered biotite. Felspar-microliths are not visible in the groundmass.[2] The other specimen exhibits the same micas; one, the more abundant, being commonly of a pale olive-green colour; the flakes generally are very small, but at one part they are ·006 to ·007 inch in length, forming a vein-like mass. The structure of the rock varies. One part probably contained angular fragments of felspar, now replaced by secondary products; another, small fragments of quartz; even a few fragments of volcanic glass possibly may have been present. As the general structure of the selvage (except for the possible substitution of glass for felspar) differs but little from that of the igneous rock of the pit, I conclude that the mass at intrusion was at a fairly uniform temperature, and this, judging from the effect on the sedimentary rock, was probably not very high.

As these rocks of the Narborough district present sometimes resemblances, sometimes differences, both among themselves and in regard to other igneous rocks in Leicestershire and Eastern Warwickshire, I determined to ascertain what variations in specific gravity they exhibited, and now append the results, obtained by using a Walker's balance.[3]

[1] Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 93.

[2] I have examined another specimen of the igneous rock of the quarry, but need only add to my former description that the rock certainly has contained biotite, and that the quartzes clearly belong to an early stage of consolidation, for in some cases they are much corroded and occasionally are enclosed by a thin ring of the groundmass. A fair idea of the microscopic aspect of this rock may be obtained from the figure of the 'micrograniulite de Luzy' in MM. Fouqué and Lévy's 'Minéralogie micrographique,' 1879 (pl. x. fig. 1).

[3] I am indebted to Miss C. A. Raisin, B.Sc., for much kind assistance. As a rule the balance was independently read by both of us, and every pains taken to ensure accuracy. When the results seemed in the least degree anomalous a second determination was made on another day.

New Pit, W. of Narborough [1]	2·62	(Mean of 4 specimens, ranging from 2·608 to 2·623.)
Narborough Pit [1]	2·65	(Mean of 3 specimens, ranging from 2·643 to 2·652.)
Croft Hill — Huncote	2·66	(Mean of 3 specimens, ranging from 2·656 to 2·659.)
Croft Hill — Croft	2·68	(Mean of 4 specimens, ranging from 2·659 to 2·701.)
Enderby — Pit S.E. of the village	2·68	(Mean of 2 specimens giving 2·674 and 2·679.)
Enderby — Rawson's Pit	2·69	(Mean of 2 specimens giving 2·686 and 2·703.)
Enderby — Enderby Company's Pit	2·70	(1 specimen.)
Stony Stanton, pits near the village	2·69	(2 specimens, different pits, 2·684 and 2·704.)
Barrow Hill — The quarry in work	2·73	(2 specimens, 2·732 and 2·734.)
Barrow Hill — The old quarry	2·72	(1 specimen, 2·718.)
Sapcote, pits S.W. of the mass	2·73	(2 specimens, different pits, 2·723 and 2·734.)
Charnwood (for comparison).		
Mount Sorrel	2·63	(A second specimen, 2·657.)
Felstone-dyke in same	2·60	
Groby — Compact reddish variety	2·65	Sheet Hedges Wood ; 2·675,
Groby — Ordinary rock	2·73	[Pool Pit.
Markfield	2·83	
Brazil Wood diorite	2·84	
Garendon (New Cliff)	2·98	(Mean of 2 specimens, 2·979 and 2·985.)
Warwickshire.		
Nuneaton Quarry, near the Midland Railway-station	2·67	(Rather decomposed.)
Quarry, by Farm, 1½ mile on the Coventry Road	2·73	(Fine-grained specimen.)
Quarry, by Farm, 1½ mile on the Coventry Road	2·85	(Coarse-grained specimen.)

Minute accuracy, it is well known, cannot be secured by this method of weighing, but I think that the results given above would not differ materially from those which might be obtained by more delicate instruments. They are a little different from what I had anticipated. The rocks of the two pits west of Narborough appear, macroscopically and microscopically, to be barely distinguishable, yet they differ in specific gravity by ·03. In more than one case specimens from the same pit vary considerably. In the Croft Pit the difference is fully ·04. There is an increase in weight eastward and westward from the new pit between Narborough and Huncote, and the heaviest rocks are those of Sapcote and Barrow Hill. I had expected the specific gravity of this last to have come out alone as the highest in the group; the result, however, justifies our classing it with the others. Again, in the case of the large *massifs*, the rocks at the southern ends seem slightly heavier than those at the northern. Our comparison of the lighter-coloured variety of the Forest syenite with the rocks of this group is also justified; for the specific gravity of the specimen from Sheet Hedges Wood Pit agrees

[1] The difference between the specific gravities of these two rocks, which seem very similar, may be due to the fact that the specimens of the first are at present a little more decomposed than those from the second locality.

very closely with that from Narborough, and that from Groby Pool Pit with the average of Croft Hill, while the ordinary rock of Groby corresponds with that of Barrow Hill and Sapcote; that from Markfield exceeding both, and all being surpassed by the rock of New Cliff. It may be only a coincidence, but, as the map shows, these three places lie on a zone running roughly north and south in the direction of the New Cliff diorites, and the Groby rock lies north of Narborough and Enderby. The general results suggest the probability of a connexion between the principal igneous masses in the Charnwood and Narborough districts, and the possibility that even those of Warwickshire may not be dissociated from them.

These rocks, so far as macroscopic and microscopic aspects go, seem to be separable into three groups, though the second in one case comes rather near to the third:—(1) The rock of the pit south-east of Enderby and the two west of Narborough; (2) that from the northern side of Enderby village, from Croft Hill, and from the Stanton-Sapcote *massif*; (3) that from Barrow Hill. The first are microgranulites, the second distinctly holocrystalline, but fine-grained. Both are porphyritic, though inconspicuously so, and both intermediate between syenites and diorites [1]; the third is a little more definitely dioritic. Though they differ, as already pointed out,[2] from the syenites of the Groby district and the hornblendic granite of Mount Sorrel, I think it probable that they belong to the same epoch of irruptive disturbance. As to the date of this we can only speculate. It can hardly be later than the Carboniferous, for the rock above the Coal Measures in the Whitwick district is basalt, and the dioritic rocks of Warwickshire (Nuneaton district) are intrusive and do not pass the unconformity at the base of the Coal-field.[3]

Sections exhibiting the relations of the Boulder Clay, Keuper Marl, and 'syenite' were more numerous and extensive than formerly, and as these are being constantly destroyed I shall venture to record a few observations. These may be grouped as follows:—(*a*) The relation of the Boulder Clay to the Keuper and the syenite; (*b*) the condition of the surface of the last-named; (*c*) the matrix and fragments of the Boulder Clay. The sections examined were: near Sapcote, in the great pit on the southern side of Croft Hill, at Mr. Rawson's pit on the northern side of Enderby village, and in the pit west of Narborough.

(*a*) The first of these sections calls for no remark under this head. At the second place the Boulder Clay was seen, at the northern end of the pit, to rest against the syenite, as the latter rises towards the

[1] Compare analyses of the Huncote, Markfield, and other Forest rocks by Mr. Berry, Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 197; and another of the Markfield rock by Mr. Player, Hatch's 'Text-book of Petrology' (1892), p. 147.

[2] Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 231, and vol. xxxviii. (1882) p. 197.

[3] On this interesting question, see the important remarks by Mr. H. T. Brown (Quart. Journ. Geol. Soc. vol. xlv. 1889, pp. 27-38) and by Mr. Strahan (Geol. Mag. 1886, p. 540).

crest of the hill. The clay presently attained to a thickness of about 16 feet, being covered by from 3 to 4 feet of soil (brownish in colour and more or less clayey). Its presence was doubtful on the western side of the pit, where the surface of the rock is higher. On the eastern it continued for some time resting on the syenite, until, as this rock gradually fell southward, Keuper Marl set in between the two. Possibly the Keuper rose very slightly in that direction; at any rate it came to the surface at that end of the pit. Hereabouts, owing to a rapid drop in the syenite—at an angle of 25° or 30°—the Marl must be full 50 feet thick. In the pit at Enderby the Boulder Clay rested against a rather irregular slope of syenite, which rose from beneath it and came to the surface on the upper part of the hill: the greatest thickness seen was about 24 feet. In the pit near Narborough the syenite did not anywhere reach the surface, but it came nearest to it (within about a couple of yards) at the E.N.E. corner. In most parts it was covered by some 20 to 24 feet of newer rocks (often about 10 feet of Keuper Marl and the same of Boulder Clay). The latter seemed to occupy a slight hollow in the Keuper, in which a distinct grey band about 3 feet thick was useful in marking an horizon. Here, as elsewhere, the banding in the Keuper drops gently away from the higher parts of the buried crystalline rock, and sometimes is slightly affected by its irregularities. Boulders of the latter are not infrequent at the base of the former. They are not, however, very numerous, and I never saw, so far as I remember, any noteworthy quantity of breccia.

(*b*) The surface of the syenite in pits near Stanton Fields Windmill showed some signs of ice-action, but these consisted, as commonly in the Forest,[1] only in the smoothing away of the crests of projecting ridges or craglets, so as to produce a surface a few inches wide. In one case I thought I could discern some slight striation.[2] But I saw between Sapcote and Stony Stanton a newly bared triangular surface of syenite (base about 30 yards, altitude about 12 yards) which was quite rough; so too was the rock exposed, as already described, in the new pit near the road to Huncote.[3] Beneath the Boulder Clay at Enderby, Croft Hill, and Narborough, the surface of the syenite, so far as I could see, varied from a gently undulating to a moderately rough slope, and afforded no distinct indication of ice-action,[4] certainly nothing approaching a *roche moutonnée*. At Narborough the grey band in the Keuper under the Boulder Clay seemed a very little wrinkled at one place, but generally the surface of the former either shelved gently below or ran almost level with the latter, and no signs of ploughing up or contortion were perceptible.

(*c*) The matrix of the Boulder Clay was generally of a bluish-

[1] Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 96. There is much information on the glaciation, etc., of the Forest region in Mr. W. J. Harrison's 'Geology of Leicestershire,' pp. 43–47.

[2] But in regard to striation here, see Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 230.

[3] Both these had been covered only by surface-soil.

[4] Attention was paid to this point in 1894 as well as on former occasions, and I feel no doubt as to the correctness of the statement.

grey colour; it became perhaps a little redder in the upper part at Enderby, and more distinctly so throughout at the Narborough pit. But it was evident that, as a rule, the materials had been derived from a distance, probably from the argillaceous rocks of the Jurassic system.[1] The 'boulders,' generally, are rather small.[2] I saw but few (*in situ*) that reached 1 foot in diameter, the great majority measuring less than 5 inches across. Among them the syenite did not appear to be common. Chalk is the most abundant rock, very often in subangular to rounded pebbles, not seldom varying 'from the size of a hen's egg to that of a duck's egg,' others being smaller. After careful examination I became convinced that, though they were frequently striated, the forms of many could not be due to the action of ice, but that they must be true pebbles, either from a beach or from the bed of a rather rapid stream (probably the former). Flints, generally more angular, were also common. Fragments of Jurassic rocks, also less worn than the Chalk, and occasionally 10 or 11 inches across, were fairly abundant. Among them were pieces of Lias (with *Gryphæa incurva*), of limestone (both from that formation and possibly from the 'Lincolnshire Limestone'), and small septaria. I found pebbles of quartz and quartzite, probably from the Bunter, and of that very hard sandstone—almost quartzite, so common in the more northern drifts, which I am told comes from the Lower Coal Measures; and a piece of crinoidal chert (Carboniferous). These are all the rocks which I certainly identified, but my time was rather limited and in some cases a close examination of the sections was not possible,[3] so the list doubtless is far from being a complete one. The chalk and flint probably come from Yorkshire or Lincolnshire.[4] The most westerly extension of Chalk in the former county is rather more than 110 miles away, in a direction about 12° E. of N.; in the latter the southern end of the Wolds (roughly to the N.E.) is almost 70 miles away, while the shortest distance to the Chalk in any direction (roughly to the S.E.) is nearly 50 miles. The presence of rather abundant pebbles, probably from a beach, at heights of from 280 to about 350 feet above the sea,[5] is difficult to

[1] The extreme edge of the Lias is between 3 and 4 miles east or east-south-east of the patches described. This is the nearest approach of Jurassic rock.

[2] They seem to run rather larger in the upper 6 feet of the clay at Croft Hill than in the lower part.

[3] As at the Croft and Narborough pits; but, on the other hand, the embankment of a new railway crossing the road between these places was made of Boulder Clay.

[4] The main object of my visit last September was to see whether I could recognize pebbles from the Chalk of the Flamborough district (which I had examined a few months previously). I can now say that the chalk is not from the northern part of Yorkshire.

[5] The height of the Boulder Clay, so far as I can make out from the 6-inch Ordnance map, is approximatively as follows:—Pit W. of Narborough, 230 feet; Croft Hill Quarry, 280 feet; at Enderby, not much less than 350 feet. The Sapcote-Stanton *massif* varies from about 250 to well over 300 feet (the churches of the two villages are each at 310 feet), so there also glacial deposits must be nearly at 300 feet above Ordnance datum. The bed of the Soar at Narborough is a few feet above the 200-foot contour-line.

explain on any theory. The absence either of well-worn rock-surfaces or of any material disturbance of the surface of the Keuper appears not to accord well with the hypothesis of an ice-sheet and a *moraine profonde*. At any rate, the journey of such a sheet up the valleys, first of the Trent, then of the Soar, must have been a long one, and the route somewhat circuitous and difficult.

Discussion.

The Rev. Edwin Hill mentioned the present extensive use of these rocks for road-material. This paper confirmed the supposed connexion with those of Groby and Garendon, but showed that their specific gravity varied in a way entirely different from the variations in their coarseness of structure. These observations agreed with those formerly made as to the absence of glacial striæ where they certainly ought to be found, if an ice-sheet had moved in any direction whatever over Central England.

Prof. Hull, while recognizing the interest attached to the Author's investigations on the igneous rocks of the district, wished to remind the Society that a very important question bearing on the geology of this part of England still remained for decision: namely, the age of the Charnwood Forest rocks. No reliable fossils had as yet been obtained from these beds; and any observer who should succeed in discovering one or more organisms of a decisive character would add an interesting chapter to the physical geology of Central England.

Mr. Rutley also spoke.

The Author said that, in regard to the specific gravity, he thought that chemical composition was a more important factor than crystalline condition. He had never been able to see that there was any reason for calling the Charnwood rocks Cambrian, other than that they were not very like any known Cambrian. He had never been fortunate enough to find any fossils.

4. *The* Tarns *of* Lakeland. By J. E. Marr, Esq., M.A., F.R.S., Sec.G.S. (Read December 5th, 1894.)

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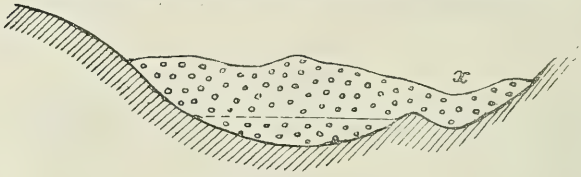
I. Introduction.

When discussing the origin of lake-basins, and maintaining the possibility of some of our English lakes lying in basins formed by earth-movement, I have often been asked whether I should consider that the basins of mountain-tarns could have been formed in that way. The difficulty of their being so formed seemed very great, and, supposing that they were true rock-bound basins, the conclusion appeared unavoidable that they were eroded by the action of ice. Some time ago I saw reasons for believing that certain tarns of Westmorland, though apparently in rock-basins, were not really so, and accordingly I have devoted some time during this year to the examination of a number of the tarns of Cumberland, Westmorland, and the Furness district of Lancashire, and now offer my observations to the Society as a contribution to the study of the origin of lake-basins, without in any way attempting to open up the question as to the origin of our larger lakes.

A casual glance at many of these tarns shows that the stream which issues from them runs over solid rock close to the surface of the lake, and this appears to have been considered by some a satisfactory proof that the tarn itself occurs in a true rock-basin. It is the object of this paper to show that such is not the case. All who have written upon the tarns of the district agree that there are some which are partially or wholly moraine-dammed at the exit (using the term 'moraine-dammed' to include such as are stopped by talus sliding down snow-slopes, as suggested by Clifton Ward in the case of Bowscale Tarn). Such moraine-dammed tarns will necessarily have a comparatively brief existence, *should the exit of the lake immediately overlie the old river-bed*, for the morainic material will be easily denuded. Accordingly we find numbers of instances of old tarns now converted into peat-bogs, owing to the temporary barrier of drift having been denuded. But there must have been many cases where the lowest point of the morainic barrier did not lie vertically above the bottom of the old moraine-filled valley. In such cases the stream would cut down

rapidly until it reached the level of the rock, and then in the majority of instances the stream would cut sideways along the junction between drift and solid rock until, when the stream reached its original position, the lake would be drained. But if a subsidiary ridge of rock lay between the position attained by the stream issuing from the lake and the position of the former valley-bottom, denudation would be retarded to so great an extent (owing to the absence of sediment in the water where it issues from the tarn) that the lakelet would become much more permanent, and its depth would be the difference between the height above sea-level of the bottom of the old moraine-filled valley and that of the present exit

Fig. 1.—*Ideal section across moraine-blocked valley.*



[For Explanation, see p. 47.]

(see fig. 1). On account of the fugitive character of the moraine-dammed tarn, where the present exit lies over the old valley-bottom, and the comparatively permanent nature of the tarn whose exit does not overlie that bottom, we should expect, even if all the tarns of Lakeland were really moraine-blocked, that the surviving ones should chiefly pour their surplus water over rock, and consequently a mere examination of the exit of a lake gives no proof of the existence of a true rock-basin. To show that such exists it is necessary to prove convincingly that no former valley, now filled with drift, occurs, which might have conveyed the waters away before it became blocked. An examination of a large number of tarns has convinced me that a valley of this kind did exist in a large number of cases, and may have existed in all the others which I have studied.

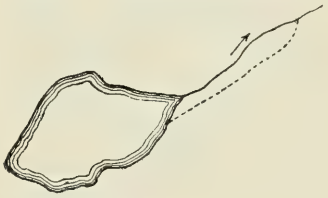
(Since writing this paper, I find the following remark on p. 43 of 'The Glacial Geology of Great Britain and Ireland,' by the late Prof. Carvill Lewis, referring to moraine-blocked lakes:—"If the moraine is compact, an outlet for the lake is often cut through the rocks, and a post-glacial gorge is formed." Prof. Carvill Lewis mentions, but does not describe cases of large lakes which he considers due to this cause.)

I propose now to consider these tarns in detail. In doing so it will be convenient to deal with them in the order in which I examined them, treating them under the following heads:—(1) Tarns near Haweswater; (2) Tarns between the Grasmere and Langdale Valleys; (3) Coniston Tarns; (4) Tarns between the Duddon Valley and Wastdale; (5) Tarns in the Scawfell Group; and (6) Tarns between Borrowdale and Thirlmere.

II. Tarns near Haweswater.

At the upper part of the Haweswater Valley are two of the most picturesque tarns in the district, namely, Bleawater at the foot of the High Street precipice, and Smallwater, below the Nan Bield Pass. The first is 1584 feet above sea-level, the second exactly 100 feet lower. I visited Bleawater before I instituted a regular examination of the tarns, but have notes that the first rock *in situ* in the stream is about 50 feet vertically below the exit from the tarn, and that an enormous semicircular moraine hems in the lower end of the lakelet, having an apparent thickness in places of considerably over 100 feet, so that there is no reason for supposing that this tarn is a rock-basin, but every reason for considering that it is not. From what I remember of the tarn, I suspect, however, that the rock may not be very far below the surface at the exit, though not exposed, and that the original valley, now moraine-blocked, lay to the north of the present exit.

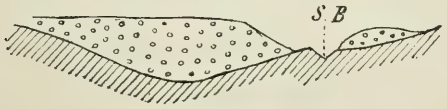
Fig. 2.—*Plan of Smallwater.*



[For Explanation, see p. 47.]

Smallwater, the first tarn which I examined with care, is fortunately also one which gives the most satisfactory proofs of the existence of a former valley, now moraine-blocked,[1] running parallel with and at no great distance from the present stream which issues from the tarn. It has not been sounded, but its comparative shallowness may be inferred from the fact that the bottom is readily visible in certain lights for more than halfway across. The present exit is at the north-eastern end of the lake, and the water runs over solid rock immediately on quitting the lake; it has worn a mere

Fig. 3.—*Section across Smallwater Beck.*



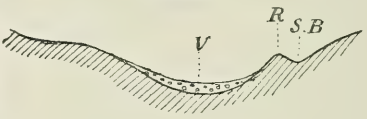
[For Explanation, see p. 47.]

groove for some distance, and then runs over a face of rock in a small waterfall. On the western side of the exit is a boss of rock, plastered with drift on the side exposed to the full force of the ice from the fell. A ridge of rock runs parallel with the stream on its right bank, and on the opposite side of this ridge is a valley blocked

[1] I use the term 'moraine-blocked,' but in this case the drift may be material which has slid down snow-slopes resting against the cliffs to the east.

up with drift close to the lake, and partially filled with drift for some distance down, but, except close to the lake, having its bottom *at a lower level than that of the floor of the present stream.* The nature of the lake, its present outlet, and the old valley (now nearly dry) may be seen from the plan and sections (figs. 2–4). The first section is drawn along the lower end of the lake, and the second about 50 yards below the present exit. The presence of the existing stream, on the side, as it were, of another valley, can hardly be explained except on the supposition that the main drainage was once down the old valley, and that when this was blocked up the water took another route, and, owing to the existence of the rocky barrier, has not been able to cut down to its former level, and so the tarn has come into existence. The old valley joins the present one about 250 yards below the exit from the tarn, and just below the above-mentioned waterfall.

Fig. 4.—*Section across Smallwater Beck.*



[For Explanation, see p. 47.]

III. Tarns between the Grasmere and Langdale Valleys.

I have examined two tarns, Easedale and Codale, occurring on the Grasmere, and one, Stickle, on the Langdale side of the watershed between these two valleys. Of these, Easedale and Stickle Tarns were considered by Prof. Hull to be moraine-dammed,[1] while Clifton Ward[2] states that Easedale Tarn is, "when the depth is considered, almost as good an example of a rock-basin as possible," and that "Stickle and Angle Tarns are probably rock-basins of a slight depth converted into tarns of a greater depth by moraines at the lower end."

Easedale Tarn has a depth of 71 feet, an exceptional depth for the Lake District tarns so far as they have been sounded, and solid rock occurs in the stream below the tarn very near the exit. I found two possible moraine-blocked valleys, filled with drift to a depth greater than the required 71 feet below the surface of the tarn, one running in a south-easterly direction along a line of lode to Blind Tarn Moss, the other starting along this lode, but curving at right angles round a boss of rock which rises above the 1000-foot contour-line, and joining the present beck 200 or 300 yards beneath its exit from the tarn. Satisfied of the possibility of a buried moraine-blocked valley, I proceeded towards Codale Tarn, but, viewing Easedale from the heights, regretted that I had not examined the ground north of the present exit, for the moraine there is of great thickness, and I suspect that the actual valley will

[1] Edinburgh New Phil. Journ. ser. 2, vol. xi. (1860) p. 31.
[2] Quart. Journ. Geol. Soc. vol. xxxi. (1875) pp. 160, 162.

be found to run from the bay north of the present exit, round the north side of Cockly Crag, and so to the present stream at Cockly Moss. This is more likely to be the case as the depression from the bay is in a direct line with the lower part of the course of the stream entering Easedale Tarn at the other end, and between these points are the deepest parts of the tarn, with soundings of 53, 60, 71, and 59 feet. However, enough was seen to show that Easedale Tarn need not be a rock-basin, though the solid rock does occur in the stream close to the point of exit.

More satisfactory evidence was obtained in the case of Codale Tarn, situated at a height of over 1500 feet above sea-level (see fig. 5). This tarn occurs in a lateral valley running in a south-south-westerly direction to join the main valley which starts from Sergeant Man, the longer axis of the tarn being parallel with the direction of the lateral valley. The stream which leaves the tarn runs at right angles to this direction, and nearly parallel to that of the main valley, which it joins a few hundred yards below the tarn. The stream at once runs over solid rock, and the exit is not at the end but at the side of the tarn. A moraine-blocked valley is seen passing from the lower end of the tarn, past Belles Knott, and quickly joining the main valley. No solid rock is visible down this partially-buried valley for many scores of feet below the lake-level, and as the tarn, from the abundance of vegetation therein, is probably very shallow, the blocking-up of this lateral valley by moraine-material would be quite sufficient to form the tarn. Much moraine is seen in the main valley where the moraine-filled valley joins it, and it is quite natural to expect that a moraine from the receding glacier originating in the direction of Sergeant Man would block the lateral valley.[1]

Fig. 5.—*Plan of Codale Tarn.*

[Scale: 4½ inches=1 mile.]

Stickle Tarn lies beneath the Pavey Ask precipice in what may

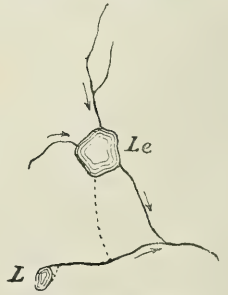
[1] These moraine-filled valleys are usually marked by continuous depressions, probably due in some cases to the accumulation of less moraine at the valley-bottom than elsewhere, but probably in the great majority of cases (where the moraine has filled up depressions and elevations to a fairly uniform height) to the greater shrinkage of the thick moraine in the valley than of the thinner material on the elevations. In the following descriptions the term 'moraine-

at one time have been a lateral valley, blocked by a moraine formed by ice coming down the main valley from near Sergeant Man, though I could not find any evidence that the tarn is not moraine-dammed at its present exit. Like many other tarns, it has an artificial dam at this point, but solid rock is not seen for some distance down the stream, and the enormous blocks of loose rock which occur in the stream here (washed out of the moraine or snow-slope screes) would prevent the drift from being rapidly denuded. I agree with Prof. Hull that this tarn cannot be considered a 'rock-basin.'

IV. Coniston Tarns.

Under this head I will consider a number of tarns lying beneath the cliffs of Coniston Old Man and its buttresses. The first of these is Lever's Water, a circular tarn, at a height of 1350 feet, which lies in a valley originating in the depression between Wetherlam and Carrs, the stream in which runs nearly due south to the tarn. The rock occurs *in situ* at the exit of the stream (Lever's Water Beck) from the tarn. This stream flows in a general south-easterly direction towards Coniston village. Just south of the lake lies Simon's Nick, a col 100 feet above the lake, with solid rock on either side. This col is situated in a moraine-filled depression, which opens southward into a deep valley (now dry throughout the greater part of its course), filled with moraine for many scores of feet below the level of the lake (see fig. 7). The valley is far deeper and more important than that through which the Lever's Water Beck flows, as may be readily judged from an examination of the 6-inch map, which, being one of a Lancashire district, has contour-lines 25 feet apart. One cannot doubt that this valley, which joins that containing the Low Water Beck at a spot called Pudding Cove, once carried the drainage of the higher part of Lever's Water Beck (known as Swirl Hause Beck), and that, when it was blocked by the moraine of the glacier coming down this valley, a tarn was formed, the water from which escaped at the present exit, forming the existing Lever's Water Beck.

Fig. 6.—*Plan of Lever's Water and Low Water.*

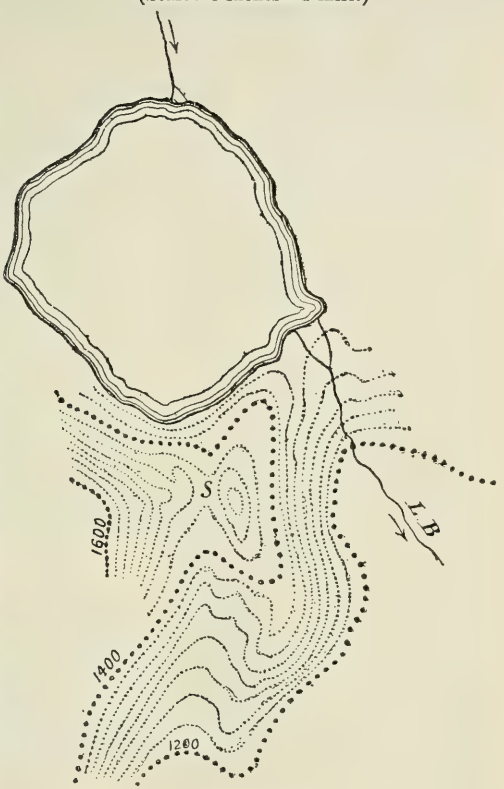


[Scale: 1 inch=1 mile.]

filled' is applied to valleys blocked with moraine below the tarn, and partially filled for some distance below. It is not to be supposed that sections are always visible when moraine-filled depressions are referred to. The absence of rock *in situ* and the general character of the ground are usually sufficient to establish the existence of moraine-matter. Its depth, of course, could be discovered only by a series of borings, which, however, it is the part of those who assert that tarns occur in true rock-basins to undertake.

Low Water (see fig. 6) is a tarn 1786 feet above sea-level, immediately beneath the summit of Coniston Old Man. It appears to be comparatively shallow, and is certainly so for some distance near the margin. No rock is seen *in situ* in the stream near the present exit, though it probably occurs at no great distance beneath the surface, but we find satisfactory indications of a former valley to the south of the present one which joined it at no great distance beneath the present exit from the tarn. This valley is moraine-filled, and in it is situated another small tarn, about 15 yards across and quite shallow (nearly filled up with vegetation), which lies in a hollow in the moraine-material.

Fig. 7.—*Plan of Lever's Water.*
(Scale: 6 inches=1 mile.)



[For Explanation, see p. 47.]

Goatswater is a small tarn lying between the Old Man and Doe Crags. I did not visit it this year, as my recollections of former visits were fully confirmed by an examination from above. The valley is blocked by the screes (probably at one time assisted by material sliding down snow-slopes) which have fallen from Doe Crags and from the cliffs on the other side of the tarn. These screes are most marked at the exit of the tarn, but they are gradually filling up the tarn itself.

Blind Tarn, farther south, at a height of 1840 feet, has no exit, from which circumstance it derives its name. There are indications of a former stream-valley (now dry) beneath it. This valley has been blocked by moraine, or, to speak more exactly, by snow-slope screes falling from the cliffs above.

Seathwaite Tarn, on the west side of the Old Man range, is a

large tarn at a height of 1210 feet. The present exit is over rock *in situ*, but the bay at the south-western angle of the tarn (south of the present exit) is continued as a moraine-blocked valley running in a north-westerly direction, and joining the present stream some distance below its exit from the tarn, south of Black Allens.

V. Tarns between the Duddon Valley and Wastdale.

Between the Duddon Valley and Eskdale lies Devoke Water, at a height of 766 feet above sea-level. This and Burnmoor are two of the largest tarns in the district, being nearly the size of Rydal Mere, usually excluded from the tarns. At the present exit of Devoke Water there are large loose blocks in the beck, but granite occurs *in situ* close to the beck and probably at no great distance beneath it. The stream from the exit runs, as is often the case with these tarns, at right angles to the longer axis of the tarn and not at its end. At the south-western end is a moraine-blocked valley, continuing to Black Beck, and the drift fills the valley (here dry) to a considerable distance below the 700-foot contour-line. As Devoke Water is only 51 feet deep, this moraine-matter is quite sufficient to block the valley and give rise to the tarn. The moraine rises at the col to a height of about 30 feet above lake-level, so that a total thickness of about 80 feet of moraine is required to cause the obstruction, a thickness far exceeded by that of many of the great moraine-mounds of the district.

North of the Woolpack Inn in Eskdale lies Eel Tarn, a small sheet of water (now largely filled up with vegetation) in a little side valley running into Whillan Beck, the stream issuing from Burnmoor Tarn. The valley may originally have drained into Whillan Beck by the course of the present stream, which shows no rock *in situ* near its exit, but it more probably drained by a more important valley (now dry and moraine-filled) north-east of the present stream.

One of the most interesting tarns that I have examined is Burnmoor Tarn, on the moorland between Eskdale and Wastdale, at a height of 832 feet. An examination of the tarn in the field shows, even more clearly than on the map, that though its drainage is into Eskdale by Whillan Beck, it is naturally situated in Miterdale. The tarn has its longest axis in a north-east and south-westerly direction, and this is also the direction of Hardrigg Gill, which enters its upper end from the slopes of Scawfell, and of the river Mite, which rises about $\frac{1}{3}$ mile below its lower end (see fig. 8). The present exit is at the east side of the north-eastern end of the tarn, nearly at right angles to the longer axis of the tarn, and the stream issuing across it is clearly seen to cut through the ridge which elsewhere separates the Esk and Mite Valleys. The maximum depth of the tarn is 31 feet. At the south-western end of the tarn, a drift-filled depression is traceable for about $\frac{1}{3}$ mile, and

suddenly ends in an interesting cirque-like cliff of rock at the head of the narrow valley which forms the head of Miterdale. Looking at this cirque from above, I at once believed that I had at last found a case of a true rock-basin, for the 800-foot contour-line runs in the middle of this cliff, and as the lake is 31 feet deep and only 832 feet above sea-level, the moraine-matter did not appear to extend to a sufficiently low level to block up the valley and form the tarn. On descending the walls of the cliff, however, I found a drift-filled gorge in its centre, running down the cliff from top to base, and only about 10 paces across. Through this gorge the drainage of the upper part of Miterdale no doubt once ran; it is now dry, the only stream here coming in at the west side of the cirque. As the col of drift between this cirque and the tarn is only about 20 feet above the tarn-level, it simply requires a thickness of about 50 feet of moraine-matter to form the lake. The infant Mite runs below the cirque for a long distance in a narrow cliff-bound gorge with an alluvial floor. It may be remarked that the drift-filled gorge in the cirque is continuous with a 'depression within a depression,' extending between this point and the tarn, probably indicating the existence of the gorge some way above the point of its exposure in the cirque.

Fig. 8.—*Plan of Burnmoor Tarn.*

[For Explanation, see p. 47.]

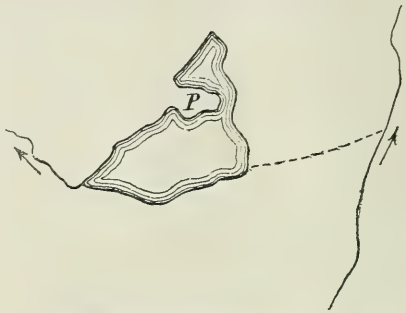
The case of Burnmoor Tarn is of interest, not only as throwing light upon the formation of some mountain-tarns, but also as indicating one of the many causes for the complexity of the Lake District drainage, which I hope to discuss elsewhere on a future occasion. Suffice it to say here that the upper two miles of what was once Miterdale is now made a portion of the Eskdale drainage-area, and the Mite is thus robbed of the distinction which it once possessed of rising on the summit-slopes of Scawfell.

VI. Tarns in the Scawfell Group.

Situated upon the northern slopes of the Scawfell group of hills are three well-known lakelets, Sty Head, Sprinkling, and Angle Tarns. None of these, so far as I am aware, have been sounded. The first, Sty Head Tarn, near the top of the Pass of that name, is 1430 feet above sea-level. It now receives the water from Sprinkling Tarn, which, as will be presently maintained, once drained in a different direction; but this stream is probably quite insignificant in time of flood when compared with the short stream descending from

the depression between Great and Green Gables by Aaron Slack, and entering Sty Head Gill just below the tarn. The exit of Sty Head Gill shows rock *in situ*, but the former valley no doubt lay east of this, and has been choked up by the dry delta which has been formed at the foot of Aaron Slack, so ponding back the water to form the tarn, for the feebler stream descending from Sprinkling Tarn or its vicinity has been quite unable to clear away this detritus.[1]

Fig. 9.—*Plan of Sprinkling Tarn.*



[For Explanation, see p. 47.]

Sprinkling Tarn (1960 feet) has its present exit over rock on its west side, but at the south-eastern corner is a moraine-blocked valley, descending into Ruddy Gill on the east, and having its floor occupied by drift for a long distance downwards; this was probably the old valley in the course of which Sprinkling Tarn now lies, and which by being moraine-blocked has caused the formation of the tarn. I do not think that anyone would claim this tarn, nearly cut in two by its steep craggy promontory on the west side, as an ice-worn rock-basin. (See fig. 9.)

A former tarn, now quite overgrown with vegetation, occurs at the head of the prominent part of the red gully at the top of Ruddy Gill, a little below Esk Hause. The stream from it goes over rock at the exit, but a moraine-blocked gully occurs just to the south, which enters Ruddy Gill a little lower down.

Between Esk Hause and Angle Tarn is a former moraine-dammed tarn, now a swamp, as the stream has cut through the moraine. It is a good example of scores of similar peat-mosses scattered through the district, showing that the tarns which now survive are but a fraction of those which once existed. These peat-mosses are noticed in answer to a possible objection that the streams ought to have cut down to the original valley-bottom. The answer is that they generally did so, but in these cases the tarns were quickly destroyed and converted into peat-mosses; only those have survived which, owing to various circumstances, had the streams below the tarns deflected from their original courses.

Angle Tarn, at the foot of Hanging Knotts, has rock at the present

[1] For a similar explanation of the lakelets of the Engadine, see Dr. C. du Riche Preller, Geol. Mag. 1893, p. 448.

exit, but on each side of this are enormous masses of moraine extending downwards for hundreds of feet into the Langstrath Valley. These are perhaps the finest moraines in the district, and they have entirely concealed any marked signs of the original valley, though the trend of the contour-lines suggests that this valley ran to the west of the present stream.

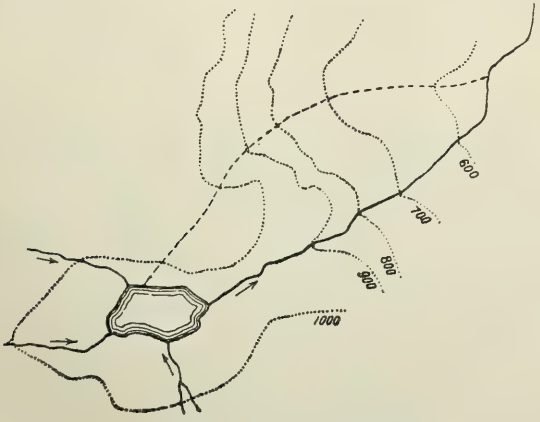
The Langstrath Valley itself takes its name from the long stretch of alluvial flat which occupies its floor for a considerable distance. A deep narrow gorge through rock at the lower end has drained the old lake, which was probably ponded up by the mass of moraine-material lying west of the gorge and blocking the valley. If this gorge were filled with drift we should find a lake above it of the character of Burnmoor Tarn.

At the foot of the Rosthwaite alluvial plain a mass of drift is plastered against the rock by the roadside; this drift probably once extended across the Borrowdale Valley and caused a lake, which was drained by the stream cutting through the drift.

VII. Tarns between Borrowdale and Thirlmere.

Watendlath Tarn, 847 feet above sea-level and 46 feet deep, was once much larger than at present. There is rock at the exit, and much rock on either side. A great mass of drift is plastered against the east side of the valley, and may have filled the old valley, but on mounting some way above the tarn I saw indications of the possible existence of a moraine-filled depression on the east side. The time at my disposal did not allow me to make as full an examination of this tarn as I could have wished, for, owing to the presence of the hamlet and of wall-enclosed fields, it is difficult to move about rapidly.

Fig. 10.—*Plan of Harrop Tarn.*



[For Explanation, see p. 47.]

Blea Tarn, at a height of 1561 feet and with a maximum depth of 33 feet, occurs higher up the same valley as that in which Watendlath Tarn is situated. There is rock on the left bank at the outlet, but a great mass of drift on the right bank far below the required 33 feet.

Harrop Tarn, the shrunken remnants of what was once a much larger sheet of water (see figs. 10 & 11), is only 12 feet deep, and has solid rock in the bed of the stream at its exit. From the northern end of the tarn, however, runs a drift-filled depression, the col of which is about 30 feet above the lake. This drift passes down a valley which is now dry and running N.W. of and parallel to Dob Gill (the present stream from the tarn), to a distance far below that required for the formation of the tarn. This valley, a short distance below the col, is much deeper and more important than that of Dob Gill, and is in direct continuation of the valley descending from the watershed between Blea and Harrop Tarns, while Harrop Tarn itself lies in a lateral valley once passing into this.

Fig. 11.—*Section across Dob Gill and valley to N.W. of it.*

Clifton Ward, in his paper on 'The Glaciation of the Southern part of the Lake District and the Glacial Origin of the Lake-basins of Cumberland and Westmoreland,' notices some tarns which I have not recently examined. Of these he admits that Red Tarn on Helvellyn and Keppelcove Tarn, a little farther north, are possibly moraine-dammed, but thinks that Blea, Little Langdale, Elterwater, Loughrigg, and Hard Tarns (the latter a small pool on Helvellyn) are rock-basins. I have seen all these tarns, except Hard Tarn, in former years, and, from what I know of the nature of the ground, I believe that old moraine-blocked valleys will be found in these cases also.

VIII. Conclusions.

It will be seen that the evidence furnished by these tarns is of different value. In the case of some, such as Smallwater, Codale, Burnmoor, Lever's Water, and Harrop, the difficulties of accounting for the conformation of the ground otherwise than by the explanation which I have offered are very great. In others the evidence is not so strong, owing to the complete or almost complete concealment of the alleged old valley by drift. But in no case which I have examined can the advocate of the rock-basin say that the buried moraine-valley does not exist. Until he can do so, I feel justified in asserting that the tarns of Lakeland give no support to the theory that the basins in which they occur were hollowed out by ice. To prove this it must be clearly shown that a moraine-blocked valley *does not* exist, whereas in some cases I maintain that

I have proved that it *does*, and in all the others which I have examined, either that it *probably* or *possibly does*.

I have not touched on the origin of the larger lakes, feeling that it would be safer to suspend for the present our judgment concerning their mode of origin. The researches of other writers have shown that they *may* be rock-basins; whether it has yet been proved that they are is a matter of individual opinion.

In conclusion I have to state that the late Mr. Topley very kindly furnished me with some unpublished soundings of some of the tarns, which are preserved amongst the records of H.M. Geological Survey at the office in Jermyn Street.

EXPLANATION OF FIGURES.

Fig. 1 (p. 36). Ideal section across a moraine-blocked valley, where the lowest part of the moraine (x) does not coincide with the originally lowest part of the valley. The diagonally shaded portion represents solid rock, that with the circles, moraine. The waters would be ponded back in the valley above the moraine, at first to the level of the top of the moraine at x, afterwards and more permanently, when the stream issuing from the tarn cut through the moraine, to the level of the broken line, corresponding with the level of the solid rock below the point x. [In the figure, the broken line is drawn a little too high.]

(If the original valley sloped uniformly on this side to its former base, the stream would no doubt cut along the junction between moraine and rock, but if a ledge of rock such as that represented in the figure projected upward, the stream would continue at the higher level.)

Fig. 2 (p. 37). Plan of Smallwater (scale: $4\frac{1}{2}$ inches = 1 mile). In this and the following plans, the streams at present entering into or issuing from the tarns are represented in continuous lines, the former courses of the moraine-blocked streams by broken lines.

Fig. 3 (p. 37). Section across Smallwater Beck (S.B.), where it issues from the tarn. Diagonal lines represent solid rock, and circles moraine. To the left of the beck is seen the former valley, now moraine-blocked.

Fig. 4 (p. 38). Section across Smallwater Beck (S.B.) about 50 yards below its exit from the tarn. R, ridge of rock separating the beck from the old moraine-blocked valley, V. Diagonal lines and circles have the same significance as before.

Fig. 5 (p. 39). Plan of Codale Tarn. Scale: $4\frac{1}{2}$ inches = 1 mile.

Fig. 6 (p. 40). Plan of Lever's Water (Le) and Low Water (L). Scale: 1 inch = 1 mile.

Fig. 7 (p. 41). Plan of Lever's Water. Scale: 6 inches = 1 mile. The course of the old valley is here represented by the contour-lines drawn (25 feet apart) between 1200 and 1600 feet in the neighbourhood of Simon's Nick (S), and the exit of Lever's Water Beck (L.B.) from the tarn. Its course is at first due south, as shown in the preceding figure.

Fig. 8 (p. 43). Plan of Burnmoor Tarn. Scale: 1 inch = 1 mile. Showing the exit from near the N. end of the tarn into Whillan Beck (W) and the position of the cirque-like cliff (C) at the head of Miterdale (M) at the point where the 800-foot contour-line crosses that valley.

Fig. 9 (p. 44). Plan of Sprinkling Tarn. Scale 6 inches = 1 mile. Showing the present and former exits, and the rocky promontory (P) nearly cutting the tarn into two.

Fig. 10 (p. 45). Plan of Harrop Tarn. Scale: $4\frac{1}{2}$ inches = 1 mile. The broken line represents the moraine-blocked valley, whilst the dotted lines show the contour-lines between 600 and 1000 feet.

Fig. 11 (p. 46). Section across Dob Gill and the old valley to the north-west of it, drawn about $\frac{1}{4}$ mile below the tarn.

Discussion.

Dr. H. R. Mill said that he had been much impressed by the Author's admirably clear explanation of the singular fact that the outlet of Smallwater flowed not along the bottom, but along the side of the valley. He congratulated the Author on having taken up the systematic study of the tarns, a class of depressions belonging to a type entirely distinct from the larger hollows of the valley-lakes. Some connecting-links, such as Hayes Water and Easedale Tarn, would probably be found on examination to bridge the gap. He thanked Mr. Marr for his paper, the conclusions of which he, as a geographer, was glad to accept without criticism.

Prof. Boyd Dawkins remarked that the Author's conclusions as to tarns being simply valleys blocked up by morainic débris applied merely to the cases cited in the area under consideration, and did not touch the general question as to the possibility of some basins being the result of ice-erosion. In his opinion the greatest lakes of the American continent were clearly proved to have been ancient valleys blocked up by glacial débris.

The Rev. H. H. Winwood did not venture to enter into the question of the origin of tarns; but, having had the opportunity of visiting Easedale Tarn in company with the Author, and on other occasions, he had examined the outlet of the stream and found that the water had cut its way through an old moraine, which was especially observable on one side.

Prof. Bonney expressed the interest with which he had listened to Mr. Marr's valuable paper. Though he personally thought little of the erosive action of glaciers, he believed that he had seen one or two true rock-basins in corries or cirques. One of the most striking examples which he had seen was the Lago di Tremorgio, south of the Ticino Valley, where live rock could be observed at the only opening, for it had been displayed in an artificial cutting.

Mr. Rutley and Dr. Blanford also spoke.

The Author, in reply, stated that his observations referred only to the tarns of the Lake District, and he considered that further evidence was required to show that tarns existed in rock-basins. He was looking forward to the publication of Dr. Mill's maps of the lakes of Cumbria, and hoped after their publication to study (with the co-operation of Prof. Nicholson) the nature of the hollows in which the larger lakes of Lakeland lie.

5. *The* Pleistocene Beds *of the* Maltese Islands. By John H. Cooke, Esq., F.L.S., F.G.S. (Read November 21st, 1894.)

[Abstract.]

For the right understanding of the Pleistocene beds, a previous knowledge of the physiography of the islands and of the earlier sediments is necessary. A full description of the physiography and of the character of the sediments, so far as they are necessary for the understanding of the accumulations forming the subject of the paper, occupies its earlier portion. Especially noticeable is the absence of ordinary anticlinal and synclinal folding, and the predominance of monoclinal faults, which largely affect the character of the surface. These faults were formed prior to the deposition of the Pleistocene beds.

The plateaux of Malta, rising to a height of 600–800 feet above sea-level, occur south of the great east-and-west fault, which has a downthrow to the north. They have no Pleistocene deposits upon their summits.

Three classes of superficial deposits are described:—

I. Valley-deposits, including (*a*) those found on the higher slopes of plains and plateaux, due to subaërial waste and rain-action, containing land-shells and mammalian bones; and (*b*) those situated at the bottoms of valleys, consisting of stratified layers of water-worn sand, gravel, and large pebbles, occurring in such order as to show that the agents which produced them have greatly decreased in intensity.

II. Agglomerates and breccias found along coast-lines and fault-terraces, always at the foot of the fault-terraces, or along the lower slopes of the depressed areas: these accumulations are either submerged or lie at the water-line. Their materials are much water-worn, and land-shells are contained in many of the layers. The agglomerates are in many cases distinctly stratified; and the Author concludes that the materials appear to have been swept down, during heavy rainfall, into the waters of land-locked creeks.

III. Ossiferous deposits of caves and fissures, which have been described elsewhere.

Discussion.

The President expressed his regret at the absence of the Author. He mentioned that Mr. Cooke, during a residence of several years, had continued the researches into the geology of the Maltese Islands initiated long ago by our Fellows the late Admiral Spratt, F.R.S., Capt. F. W. Hutton, the Earl of Ducie, and the late Dr. Leith Adams. Later the geology of Malta had attracted the notice of Dr. John Murray, F.R.S.E., who was guided over the island by Mr. Cooke, and had written on the subject of its geology. Doubtless the cutting out of the physical features as we see them is the result

of denudation which was active when Malta was part of a much larger area than at present, and connected with the neighbouring continents; when it had a larger rainfall, and a fauna consisting of elephants, hippopotami, deer, bears, etc., suggesting continental conditions.

Prof. Hull recognized the careful manner in which the Author had worked out the structural features of the islands, and had shown by his section the submarine relationship between the strata of Malta and Gozo. He was also gratified by finding that the Author admitted that the present streams and amount of rainfall were quite insufficient to account for the deep valleys cut down through the plateaux. He concurred with him in believing that they pointed to a former condition of these islands when they formed a part of an extensive land area, now submerged, and a period of greater rainfall—namely, that known as the Pluvial—intermediate between the Pliocene and the present. That Malta once formed a portion of the causeway connecting Europe with North Africa was a view that had the support of several geologists, including the late Admiral Spratt and the late Dr. Leith Adams, and one in which he (the speaker) fully concurred.

Mr. Monckton asked whether the facts brought forward as evidence of a recent submergence of the islands did not rather point to an increased altitude, possibly accompanied by great rainfall and snow. The presence of land-shells and the absence of marine or fluviatile remains seemed also to favour elevation rather than subsidence.

Dr. Du Riche Preller agreed with the previous speaker that a gradual emergence of the Maltese Islands was much more likely than the submergence in Pleistocene times suggested by the Author; the more so as Gastaldi on geological, and Forsyth Major on independent biological grounds, had demonstrated the former existence of a Mediterranean continent, of which the Maltese Islands must also have formed part.

Dr. J. W. Gregory referred to the excellent work done by Mr. Cooke in the zonal collection of fossils from the Oligocene and Miocene rocks of Malta, and had no doubt this paper contained a mass of carefully observed facts. He hoped that these would throw light on the direction of the old river-valleys in the days before Malta was reduced to its present size. He doubted whether any of these Pleistocene deposits could have been formed during the emergence of the island from the sea, as there seemed no evidence of its submergence since the Tortonian or Upper Miocene epoch.

Mr. Marr also spoke.

6. *The* Marble Beds *of* Natal. By David Draper, Esq., F.G.S.

(Read December 5th, 1894.)

I. *Introduction.*—Early explorers in Natal mention the occurrence of marble along the lower course of the Umzimkulu river. Mr. C. L. Griesbach (Quart. Journ. Geol. Soc. vol. xxvii. 1871, p. 56) described the position of this "crystalline limestone of enormous thickness," but could not determine its relation to the neighbouring rocks. During his visit to the colony, that portion in which the marble is situated was entirely occupied by natives, and covered by dense bush; consequently exploration was difficult. Since then roads have been cut through the country, and numerous farmsteads have been built by the whites on the more fertile tracts of land.

The settlers along the banks of the Umzimkulu have endeavoured to establish an industry in connexion with this marble, several lime-kilns and a small cement-factory having been erected; and small shipments of the marble are occasionally sent to Durban, for building or statuary purposes. Still more systematic attempts might be made to develop this valuable marble, the only one known to exist in South Africa.

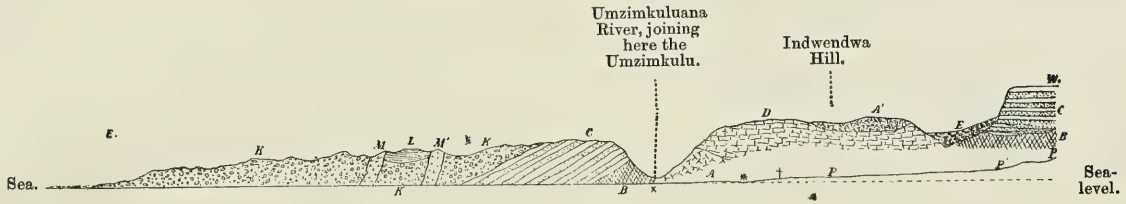
II. *Situation.*—The area occupied by the marble is in the county of Alfred, the southernmost county of the colony of Natal. The Umzimkulu river, rising in the Drakensberg and flowing eastward, enters the Indian Ocean about 30 miles north of the southern boundary of Natal; about 7 miles from its mouth it is joined by the Umzimkuluana river. The marble area occurs in the two river-valleys, and is about 16 square miles in extent.

III. *Physical Features of the Country.*—Along the coast-line, and extending about 6 miles inland, the country consists of small, rounded hills, reaching to a height of about 700 feet above sea-level; but farther inland flat-topped hills take their place. Numerous rivers having cut their way through the hills to the sea, deep valleys have been eroded by them.

The deepest and most precipitous are those of the Umzimkulu and the Umzimkuluana rivers, which are from 700 to 1200 feet deep, and bordered by crags and precipices, in some instances the full depth of the valley. The courses of both these rivers are over successive cataracts and falls to within 7 miles of the Indian Ocean; and from there the united stream, thenceforward called the 'Umzimkulu,' is navigable by small craft.

Westward of the junction of the two rivers is a deep, roughly circular valley, about 36 square miles in extent, surrounded by crags, and intersected by the rivers above mentioned. In the fork between the rivers a ridge or small range of hills is situated, connected with the table-land to the west. The valley is extremely

Fig. 1.—*Section from the Coast to the Hills, 13 miles inland, showing the position of the Marble with regard to rocks in its vicinity.*



A = Granite.
A′ = Granite exposed by denudation.
BB = Clay-slate.
CC = Table-mountain Sandstone.

D = Marble.
E = Débris.
KKK′ = Dwyka Conglomerate.

L = Ecca Shale.
MM = Dolerite Dykes.
PPP = Course of Umzimkulu River.

* = Position of marble with chloritic schist, etc. † = Intrusive dyke of porphyritic granite. × = Fault.

rugged, and covered for the most part with dense bush and long grass, greatly increasing the difficulties of exploration.

Bare rock (principally marble) lies in isolated patches in the bush, and loose boulders and rock-masses are numerous under the crags and in the rivers.

IV. *Geological Conditions.*—From the coast inland for a distance of about 5 miles, Dwyka Conglomerate, similar to that found in the Cape Colony and Natal, is the prevailing rock. Petrographically it presents no special features, but has evidently been greatly disturbed, presenting undulating lines, as though it had been subjected to pressure. Cleavage-planes are numerous up to the first fault (the dyke), marked M in the section facing this page.

Two such dykes, M, M′, lying about 1 mile apart, and each more than 100 yards in width, have intersected the Dwyka Conglomerate (see fig. 1). They consist of dolerite, similar to that found in connexion with the Ecca Shales and Dwyka Conglomerate farther inland.

Between the dykes, a small patch of Ecca Shale, lying a few feet lower than the conglomerate on the outer side of the dykes, has survived. The Dwyka Conglomerate between the dykes passes gradually into Ecca Shales, and their line of junction is not defined.

Westward of the second dyke, M′, Dwyka Conglomerate again crops out, lying upon Table-mountain Sandstone, C, both dipping eastward.

The last-named formation consists principally of coarse gritty sandstone, similar to that found in the Table Mountain at Cape Town. The conglomerates which generally occur in connexion with this series are here represented only by thin lines of coarse grit and small pebbles.

The Table-mountain Sandstone rests upon clay-slate, of which series, however, only small portions are exposed; the principal outcrop is on the eastern side of the Umzimkuluana valley, at the junction of that river with the Umzimkulu. Up as far as St. Helen's Rock, a crag about 200 feet high, marked B in fig. 1, the river is tidal.

Proceeding westward, the next rock met with is granite; and, as it rises to an altitude of over 700 feet in the ridge known as the Indwendwa Hill (along the sides of which the principal marble masses, roughly stratified, are situated), no doubt a great fault exists, which has lowered all the rocks eastward of the fault.

The granite is grey in colour, and remarkably poor in mica; it is covered by the marble, but shows through whenever the marble has been removed by atmospheric influences or erosion. The junction between the marble and the rocks west of it is obscure, the whole surface being covered by débris (E) from the hills. The upper portion of these hills consists of Table-mountain Sandstone, resting upon clay-slate.

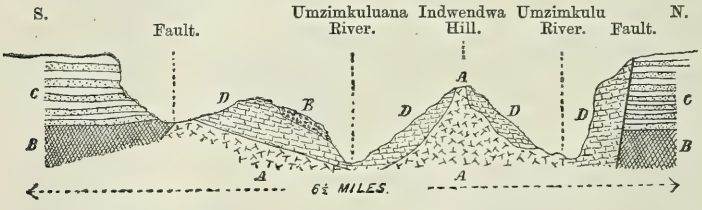
A small mass of marble, at * in fig. 1, detached from the main body, now lies tilted to an angle of about 80°, and surrounded

by granite [boulders ?] except on the eastern side, where some chloritic schist, apparently also a detached block, occupies a small area.

An intrusive dyke of flesh-coloured porphyritic granite (very similar to Shap granite) has disturbed the marble beds at the spot marked † in fig. 1, p. 52.

The accompanying section (fig. 2) shows the position of the marble-beds with regard to the rocks in their immediate vicinity.

Fig. 2.—*Section across the river-valleys, showing the position of the Marble.*



AAA = Granite.
BB = Clay-slate.
CC = Table-mountain Sandstone.
DDDD = Marble.
E = Débris (ancient course of river).

The Indwendwa Hill occupies the area between the two rivers, and extends to their junction. It consists mainly of granite, covered with marble, except where the latter has been removed by natural causes, as at the top of the hill A in the above section.

The marble is obscurely stratified, dipping apparently towards the river-valleys on both sides, and having an east-and-west strike.

The quality of the marble varies from coarsely crystalline limestone to the most finely grained statuary marble, and the colour from purest white to deep red. The coarsely crystalline variety contains from 5 to 13 per cent. of carbonate of magnesia.

A deposit of tufaceous limestone, evidently derived from the weathering of the marble, covers the latter in some places with a layer several feet in thickness. The percentage of magnesia is much smaller in this tufa than in the solid marble.

V. *Conclusions.*—The marble-beds of the Umzimkulu valley are the only examples of this rock discovered up to the present time in Southern Africa; and by reason of their mode of occurrence, position, and general surroundings, they constitute the most interesting feature in the geology of the Natal coast.

The first question that presents itself is—What is the geological period to which they belong?

Wherever I could discover any rock immediately underlying the marble, it was granite; and there is no doubt in my mind that the calcareous matter of which the marble was formed was deposited on the granite. At one spot marked * in the section (fig. 1, p. 52) a

block of marble, detached from the main body, was seen in the granite, together with a small mass of chlorite-schist, similar to that of the Malmesbury Beds of Cape Colony. The small piece of chlorite-schist was all that I could find in the valley, and it is no larger than the block of marble in its vicinity. Both the marble and the schist appear to be surrounded by granite, and project out of the granite-mass. Both are detached blocks. This is the only evidence of the Malmesbury Beds being below the marble; but, if taken in conjunction with the fact that in no instance could I find any trace of the chlorite-schist (Malmesbury Beds) in the travelled blocks *upon* the marble in the valley, I think that the evidence is in favour of the marble being younger than the chlorite-schist.

Evidences of great disturbances of the strata are numerous in the rocks surrounding the valley. The greatest displacement occurs at the junction of the rivers, where a fault, marked × in fig. 1, p. 52, has let down the strata, until the Table-mountain Sandstone, which at one time was no doubt a portion of the plateau (shown in the western extremity of the section), is now 500 feet lower in elevation, and steeply inclined to the east. Again, the northern boundary of the marble is against Table-mountain Sandstone (see fig. 2, p. 54); and here evidences of a fault are conspicuous in the abrupt manner in which the two rocks terminate against each other.

Nowhere could I find evidence of the marble-beds extending under the hills in any direction around the valley. It is certain, however, that the marble does not lie between the Table-mountain Sandstone and the clay-slate; nor is it connected with any of the newer formations, up to the Ecca Beds.

That it was deposited before the granite was disturbed is evident by the dip of its beds, indicating that the upheaval of the granite placed them in their present position, as an anticlinal with a synclinal on each side of it. I could find no traces of organisms in the marble, nor in the tufaceous limestone.

Though sections of all the rock-formations from the granite to the Ecca Beds are numerous in the stretch of country lying between Durban and the Umzimkulu, no trace of marble or other limestone, excepting the tufa, has been discovered up to the present time in these parts.

Judging from the evidence, which I have endeavoured to explain in the foregoing paragraphs, it appears to me:

1. That the calcareous material from which the marble has been formed was deposited upon the granite, and possibly on the Malmesbury Beds, before their disturbance.
2. That faulting has displaced the beds surrounding the valley.
3. That the marble is of local occurrence, extending only for a limited distance under the surrounding hills.
4. That its place in the geological sequence is subsequent to the deposition of the Malmesbury Beds, and that these latter show no signs of having been extensive here.

5, and finally. Since the marble-beds were placed in their present position they have been extensively eroded by the rivers, which have deepened their courses to their present level; but the numerous pebbles and boulders found along the hillside (more especially at the spots marked E in figs. 1 & 2, pp. 52, 54) are evidences of these rivers having occupied a much higher line at a comparatively recent date.

Note.—The Cretaceous beds of the Umtamfuna river are about 30 miles south of the locality where the marble occurs.

Discussion.

Dr. Du Riche Preller regretted that the paper appeared to contain no suggestion whatever regarding the probable age of the granite and marble respectively, nor any indication that the contact-lines had been examined to determine the relation of these rocks to each other. The two sections given in illustration of the occurrence were contradictory; for while in one section the marble rested like a sheet or mantle on the granite-masses, in the other the marble-mass was wedged in between the granite. In the first section the marble appeared, as the Author concludes, 'deposited': that is, it would be compact limestone subsequently rendered crystalline by lateral or superincumbent pressure; whereas in the other section the granite below and above might be the remains of a fold such as is met with in the schists and marble strata of the Carrara district. Seeing that the marble was stated to contain about 15 per cent. of magnesia, it seemed to be of a dolomitic nature rather than strictly saccharoidal limestone like Carrara marble, which latter contained at least 93 per cent. of carbonate of lime.

Prof. T. Rupert Jones also spoke.

7. Geological Notes *of a* Journey *in* Madagascar.

By the Rev. Richard Baron, F.L.S., F.G.S. (Read November 21st, 1894.)

[Plate I.—Map.]

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I. Introduction.

In the course of the year 1891 it fell to my lot to undertake a long and interesting journey of about 1200 miles in the island of Madagascar, during which I was able to make a few geological notes that may not be unworthy of record. Leaving the capital, I proceeded in a north-easterly direction as far as Imerimandroso,[1] in the province of Antsihanaka; then struck due east, reaching the sea at Fenoarivo, a town situate about lat. 17° 25′ S. From here I followed the eastern coast, mostly along the water's edge, as far as the Bay of Diego Suarez, in the extreme north of the island; and thence I travelled down the north-western coast as far as the River Mevarano, in lat. 14° 37′ S., finally proceeding by boat to the island of Nosibe (long. 48° 15′ E., lat. 13° 20′ S.), visiting several of the smaller islands on the way. It is, of course, impossible to give a detailed account of the geological features of the country traversed during such a journey; but, as so little is known of the geology of Madagascar, a general sketch may not be without value. I may say that specimens of all the different rock-types met with on the route were collected, and I hope to give a detailed description of them as soon as practicable.

For the sake of convenience, the part of the island travelled over may be divided into four sections: (1) that between the capital and the east coast, (2) the east coast (that is, the northern half of it), (3) the northern end of the island, and (4) the north-west coast and islands. These I shall now briefly describe in order.

II. The Country between the Capital and the East Coast.

By far the most predominant rock between Antananarivo, the capital, and the east coast is a hornblende-granitite-gneiss. This rock, which covers so wide an area in the eastern half of Madagascar, is, for the most part, of a greyish or bluish-grey colour and of medium texture, and consists essentially of felspar (orthoclase and plagioclase), quartz, dark mica, and hornblende. It not infrequently becomes garnetiferous, but otherwise generally varies little in minera-

[1] Except when otherwise mentioned, the native names are those of towns and villages.

GEOLOGICAL SKETCH-MAP
OF THE
ANTSIHANAKA PROVINCE.
By R. Baron.
Scale of Miles,
0 1 2 3 4 5 6 7 8 9 10
Small volcanic cone. (Nepheline-basalt)
Hypersthene-rock.
Quartz-magnetite and Quartz-actinolite rock.
Norite and Olivine-norite.
Gneiss.
48°
30'
45'
49°
Ankitsika
Ambohijanahary
Imerimandroso
Lake Alaotra
Alaotra Valley
Amparafaravola
Undulating country showing old lake levels.
Old lake beds (partly marsh, partly grass land).
Ambatondrazaka
Very coarsely foliated gneiss
Part of central mountainous range of gneiss.
48° Long. E.
45'
30'
45'
49°

logical composition. For many square miles (how many I cannot say) in the neighbourhood of the village of Sahatavy, about 20 miles west of Fenoarivo (east coast), the rock assumes a very distinctly banded structure, consisting of layers of white felspar (orthoclase and plagioclase), quartz, and dark mica, and is also somewhat garnetiferous. This is the most distinctly and beautifully banded gneiss that I have seen anywhere in the island. The prevailing direction of the strike of the rock between the capital and the Antsihanaka province, including the latter (the limits of which province may be given as about long. 48° 20′ E. to long. 49° E., and lat. 17° S. to lat. 18° S.), is north-west and south-east, or north-north-west and south-south-east, although the general strike of gneiss in the island is a few degrees east of north and west of south. When I speak of the strike of the rock, however, I mean the strike of the foliation. As far as my observations of the Madagascar gneiss and its allied rocks go, the foliation appears to coincide with bedding—at any rate with the chief divisional planes. East of the province of Antsihanaka, however, as far as the coast, the rocks assume the prevailing trend of a few degrees east of north and west of south.

In the Antsihanaka province itself another type of rock comes into great prominence, though not to the exclusion of the gneiss: this is olivine-norite. (See the map facing this page.) It occupies a very large area (not improbably at least 200 square miles), though its precise boundaries are unknown. It rises into numerous fairly big hills, and is doubtless the rock underlying Lake Alaotra,[1] as it is found abundantly on both sides of the water. The grains of olivine in this rock are surrounded by a shell of hypersthene, outside which is a layer of actinolite. But norite without olivine also occurs. Occasionally the norite contains almandine-garnet. It is generally, though not always, fairly well foliated. The strike of this norite is also north-west and south-east, or north-north-west and south-south-east. Numerous patches of amorphous quartz, often milky-white in colour, make their appearance in the norite and crop out on the surface.

Coarse hypersthene-rock occurs in a *massif* or immense boss on the west side of Lake Alaotra. At the north and north-east end of the lake there is a very large exposure of quartz-magnetite rock, covering an area of many square miles. In some portions of it the magnetite appears to be almost or quite as abundant as the quartz. Occasionally, as between the villages of Imerimandroso and Tsarahonenana, the magnetite is replaced by thin layers of a golden-looking mineral, which proves to be a ferruginous actinolite. In the south-east of Antsihanaka the gneiss is exceedingly coarsely foliated, some of the folia swelling out to a foot or even a yard in thickness. Amongst these pegmatite and graphic granite occasionally occur, as, for instance, at the village of Mangalaza. These are apparently part and parcel of the crystalline rock itself, and not

[1] For an account of this extensive ancient lake, see my former paper in Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 306.

fissure-injections. Very thick folia of hornblende, or hornblende with a little felspar, are also noteworthy.

Other rocks occurring in this province of Antsihanaka are:—

Crystalline limestone and serpentine, near Ambatondrazaka, the capital of the province;

Hornblende-pyroxene-granulite (123 [1]), pyroxenite (Hunt) (113), and nepheline-basalt (124), near Amparafaravola, a village on the west side of Lake Alaotra;

Limburgite (114, 115), near Mount Ambongobe, south-east of the village of Ambatondrazaka;

Also a kind of trap-granulite (236).

The country between the Antsihanaka province and the east coast is of a very mountainous character and is largely occupied by forest, the rock being so thickly covered over with soil and decayed vegetation that there are comparatively few good exposures. Sufficient evidence is, however, forthcoming to show that the rock is chiefly gneiss. About 6 or 8 miles east of the village of Ankaitomboka (long. 49° E., lat. 17° 20′ S.), on the eastern boundary of the Antsihanaka province, a form of trap-granulite without a rhombic pyroxene occurs (264). About 5 miles east of the same village another form of the same rock occurs (283), but this time without garnet. Some of the trap-granulites might perhaps be styled norites, but their structure is thoroughly granulitic. Olivine-basalt (329) occurs also to a small extent in this neighbourhood. Between the villages of Tsarasambo and Salangina (about 25 miles east of Fenoarivo) there is an exposure of garnet-rock, consisting of red garnet and ordinary green hornblende, though some portions of it are composed almost exclusively of garnet. It may be an extreme form of trap-granulite. There are also, especially as one nears the sea, several dykes of dolerite, sub-ophitic in texture, which run in a generally north-and-south direction. It matters not from what point in the interior the country is traversed to the east coast, these dolerite-dykes are invariably met with. On the road, for instance, from the port of Tamatave to the capital there are at least six or eight such dykes, the most westerly of which is about 45 miles, and the most easterly about 8 miles, from the east coast. This fact, along with the almost unvarying similarity in mineralogical and textural character of the rock composing these dykes, points to the conclusion that they run continuously for great distances along the lower eastern slopes of the island. If the freshness of their condition be any criterion of their age, they belong to a comparatively recent geological period.

III. The East Coast.

Perhaps the most notable fact in regard to the geological structure of the northern half of the east coast (as also, so far as I can learn,

[1] The numbers in parentheses throughout this paper refer to the microscope-slides in my collection.

of the southern half) is the preponderance, among the rocks exposed, of dolerite. From Fenoarivo to, say, lat. 14° S.[1]—a distance of about 200 miles (and my journey led me for the most part along the shore)—one sees comparatively little else than this dolerite; occasionally, however, the underlying gneiss comes to the surface. The question arises, therefore,—Whence has it been derived? The only satisfactory explanation of its occurrence seems to be that it has flowed from large fissures farther inland, which at present are represented by the dykes above referred to. This I conclude from the following facts:—(1) The exact similarity, for the most part, in mineral composition and texture of the dyke-rock with that on the coast. I have examined microscopically several dozen sections of both. They consist almost always essentially of plagioclase and augite, and show subophitic, or very seldom typically ophitic, texture. Occasionally they contain also a slight amount of olivine. (2) The persistence of this one type of rock for so great a distance along the coast in a north-and-south direction. This is easily accounted for on the supposition of a dyke or series of dykes a few miles inland (which, as before stated, actually exist) running more or less parallel with the coast, from which lava has issued. (3) In some places the rock is distinctly traceable as a lava-sheet for several miles inland; and as there is no large volcanic vent or series of vents ranging parallel with the coast from which it could have flowed, the dykes above referred to must be looked upon as its source. For these reasons I conclude that fissure-eruption has occurred on a large scale on the eastern side of Madagascar. The subophitic and ophitic textures also seem to suggest that the flow has been of considerable thickness.

The lava-sheet has been, at least in some places, enormously thick. A few miles north of the coast-town of Antalaha (lat. 14° 57′ S.), for instance, it covers the country to a great depth for several miles inland—how many I cannot say. In other localities numerous hills, some hundreds of feet in height, composed entirely of dolerite, stand as witnesses to the great volume of the lava-flow. This thickness may account for the prevalently doleritic texture of the rock; only occasionally is it basaltic. The lava has in many places been entirely removed by denudation, and in other places it is covered by dense, impenetrable forest. The rock is almost always compact in texture, though in a few places it is vesicular: for example, at the locality known as Ambatofaingainy (532), lat. 15° 8′ S., about halfway between Ngontsy and Antalaha, where it is amygdaloidal, the vesicles being filled in with calcite, quartz, dark green chalcedony, chlorite, and zeolites; the cracks in the rock being occupied by ferruginous matter and chalcedony. The rock at this locality is a basalt, or perhaps an andesitic basalt. A quite exceptional type of dolerite occurs at Antalaha itself (271), the tolerably large crystals of plagioclase and augite being embedded in brown tachylytic glass.

[1] When the longitude is not given, the place indicated is on or near the sea-coast.

This glass occupies more than half of the rock and is crowded with black trichites. At one place (about lat. 15° S., a mile or two from the sea) I noticed some volcanic breccia. Here and there are to be seen volcanic dykes cutting through the gneiss or granite on the sea-shore, the rock from which sometimes proves to be the usual subophitic dolerite and sometimes basalt. A doleritic dyke (376), for instance, occurs immediately south of the small village of Antseranambe, south of Antongil Bay. The rock at the margin of this dyke contains a considerable amount of black tachylyte (278). A basaltic dyke is to be seen 2 or 3 miles north of the village of Manompana, opposite the island of Ste. Marie. In this instance it cuts through dolerite, the basalt itself assuming a somewhat andesitic habit (373). Another dyke of basalt (317) (approaching to dolerite in texture), which may be called doleritic basalt, occurs at the village of Tanjona in Antongil Bay. Doubtless other dykes occur which are covered by the sand of the sea-shore.

Although by far the greater part of the lava has consolidated in the form of dolerite, there are one or two localities where it has assumed a much finer grain and occurs as basalt. At Isoavinandriana, for instance, the capital of the province of Sahambavany (lat. 14° 10′ S.), many square miles of country are covered by a basalt of exceedingly fine grain and of somewhat andesitic habit (275). At the River Lokoho, again, some 3 or 4 miles south of Isoavinandriana, the rock is also a basalt (310) with andesitic habit. At Amboaniho (lat. 13° 25′ S.), the capital of the Iharana province, basalt also occurs (303–307).

At this same town of Amboaniho, and for several miles north and south of it, as also for some distance inland, occurs another type of rock in great abundance, namely, felspar-porphyry (302, 465, 468). Spreading, as it does, over a wide area, and forming very thick masses, there can, I think, be no doubt as to its being an actual lava-flow; but from what source it has proceeded I cannot say. Nothing, however, suggestive of volcanic cones is to be seen anywhere, so that this flow also may possibly have issued from a fissure or fissures in the crust. It varies more or less in character. Sometimes it is dark-coloured, almost black, with phenocrysts of flesh-coloured crystals of orthoclase. Its prevailing colour is, however, purplish. Occasionally the rock is quite or almost free from phenocrysts of felspar, when it may be called felsite. Felspar-porphyry, together with felspar-porphyry breccia (300), both of a purplish colour, occur in a hill 500 or 600 feet high, about 1 mile south of the village of Amboaniho (lat. 13° 25′ S.), the breccia lying above the porphyry, and this again being underlain by somewhat altered basalt (304–307), which forms the base of the hill. In other places the felspar-porphyry becomes spherulitic (for instance, about 12 miles south of Amboaniho), the spherules being small but very numerous.

Felspar-porphyry occurs in small quantity also farther north, namely, about 2 miles south of the village of Andravina (about lat. 13° S.).

Quartz-porphyry (453, 454), felsite? (449), and rocks with

abundant epidote are also found in the neighbourhood of lat. 13° 17′ S., a mile or two from the sea.

In one or two localities occur considerable areas of granitite (biotite-granite), as, for instance, in the neighbourhood of Vohijanahary (lat. 16° 10′ S.), the capital of the Mananara province. Another extensive area, but of unknown limits, north of Antongil Bay, in the neighbourhood of long. 50° E., lat. 15° 20′ S., taken as a central point, consists, for the most part, also of granitite. All the slides taken from the rock of this locality show under the microscope that it has been subjected to much mechanical disturbance, the structure being that known as cataclastic. The rock has here been very extensively invaded in all directions by dykes and bosses of epidiorite (387); this is especially the case some 8 or 10 miles north of the head of Antongil Bay (in the neighbourhood of the village of Fizôny); but epidiorite also occurs now and then in dykes as far south as lat. 12° S. and as far north as lat. 13° 15′, where it forms fairly high hills (463). The epidiorite occasionally shows spheroidal weathering. In one locality (about long. 50° 10′ E., lat. 15° 5′ S.) I found in the bed of the River Sahafihitra numerous blocks of chiastolite-slate and argillaceous schist, but I nowhere met with these *in situ*. Quartzite occurs also in various localities in the neighbourhood of this granitic area. Of the precise field-relations of these rocks I cannot, I am sorry to say, give any particulars, having crossed the area only in one direction, and that somewhat hurriedly; but that the granitite is eruptive seems to be indicated by the existence of the chiastolite-slate, and also, not improbably, by the quartzite.

Aplite occurs also in considerable quantity in various localities, as 2 or 3 miles north of Manompana (lat. 16° 43′ S.), at Manambato (lat. 16° 33′ S.), at Manakambahiny (long. 49° 43′ E., lat. 15° 8′ S.), and at Ampanobe, 2 or 3 miles from the sea (lat. 13° 40′ S.).

Other rocks found on this eastern coast-line are:—

Hornblende-schist (263) (probably much altered epidiorite).	Three miles north of the village of Andranovola in Antongil Bay; 4 or 5 miles south of Soanierana, at the head of Antongil Bay (269, 270); and also in the neighbourhood of the village of Sahaka, opposite the island of Ste. Marie.
Augitic quartz-diorite (312) .	Village of Sahaka, opposite the island of Ste. Marie.
Mica-schist, crowded with crystals of blue kyanite, often a couple of inches in length.	Soamianina, opposite the island of Ste. Marie; and also several miles south of it.
Norite (374, 375)	Three or four miles north of the village of Antanambe (lat. 12° 25′); and a little south of the village of Tanjona, in Antongil Bay.

Diabase (279)	A few miles north of the town of Vohimarina, lat. 13° 20′ S.
Hypersthene-dolerite? (363) (or norite?).	Village of Mandrisy, opposite the island of Ste. Marie.
Epidote-rock (425)	Long. 50° 10′ E., lat. 15° 5′ S.
Epidote-schist (356)	Near Soamianina, opposite the island of Ste. Marie.
Volcanic tuff (446)	About lat. 13° 50′ S.

It may not be unworthy of note that pieces of pumice from Krakatao lie strewn along the entire length of the east coast.

Before concluding the remarks relative to the northern half of the east coast, it may be mentioned that, although the rivers are numerous, none of them can be spoken of as large. Close to the sea, however, most of them assume a considerable width, but this is owing to the heaping-up of sandbanks by the ocean waves. A few miles inland they are mere streams. Some of them form lagoons several miles in length, and what is sometimes given as the northernmost limit of the numerous lagoons of the east coast is not actually correct, although those north of Tamatave are by no means so numerous or so large as those south of it.

IV. The Northern End of the Island.

The part of the island here referred to is that which lies north of lat. 13° S. In the neighbourhood of Andravina (lat. 12° 28′ S.), on the eastern sea-board, and some miles south, there are numerous patches of thick loose sand extending 3 or 4 miles inland. These are apparently marine deposits. The River Lokia, a few miles north of lat. 13° S., marks as nearly as possible the boundary-line between the crystalline and the sedimentary rocks in the northern part of the island, for while immediately south of the river there are here and there a few outcrops of sandstone lying on the crystalline rock (granitite), north of the river the central mountain-mass (which is merely the end of the great mountain-chain forming the backbone of the island) is composed of sedimentary strata, sandstone appearing first, succeeded a little farther north and overlain by oolitic limestone (467, 511, 519). This mountain-mass is not improbably 1200 or 1400 feet high. On the east side of the island it approaches the sea, being very steep, and leaving for the most part a flat belt of low-lying land at its eastern base of only a mile or two in width, and averaging perhaps 100 or 200 feet above the sea. On its western edge it is much more broken up and somewhat lower in altitude, and is composed of fossiliferous sandstone and oolitic limestone (480, 516). A comparatively flat area of varying width, but probably averaging about 20 miles, extends from its western base to the sea. Its extreme northern limit, where it forms a steep bold front running for some 15 or 20 miles in an easterly and westerly direction, and where it is composed mostly, if not entirely, of oolitic limestone, occurs at lat. 12° 45′ S. The dip of

the rock is generally 10° to 15° N.W., and the actual thickness of the limestone must be very considerable. The River Lokia, therefore, which runs from west to east, is probably situated where the northern coast of the island lay in Jurassic times, and may be taken as the present northerly limit of the outcrop of the gneiss and allied rocks that form the greater part of the eastern half of the island. I say 'Jurassic times,' because, judging from the fossil contents, which have been examined by Mr. R. B. Newton, F.G.S., there can be no question as to the age of these sandstones and limestones (though the latter may be in part Cretaceous), for although many of the fossils have a wide range of distribution, some of them can be classified with certainty as belonging to the Jurassic series of rocks. (See his paper, following the present one.)[1]

Between lat. 12° 45′ S., where the mountain-range very abruptly ends, and Diego Suarez Bay (about lat. 12° 15′ S.), the chief feature of interest is the mountain of Ambohitra, which is situated about one-third way across the island, being nearer the west than the east coast. The position of its highest point is about long. 49° 10′ E., lat. 12° 40′ S. It runs in a direction north and south for a distance of 10 or 12 miles and is probably about 5000 feet high, the highest point I attained being 4100. It is an extinct volcano, and has poured out lava which has flooded the low-lying country from sea to sea, and from Diego Suarez Bay in the north to about lat. 12° 35′ on the eastern, and about 12° 50′ on the western side of the island to the south.[2] The area thus covered by the lava is probably no less than 1200 square miles. One small crater, now occupied by a lake, I discovered high up on the mountain, and another and larger lake, probably also a crater, is said to exist near the summit. The rock, from whatever locality it be taken, whether from the town of Diego, on the southern side of Diego Suarez Bay, or any other part of the lava-bed, or from any part of the mountain itself, is remarkably homogeneous in character: it is an olivine-basalt of a dark grey colour, the olivine-crystals being largely altered to serpentine. The upper part of the bed, where not decomposed into soil, is often very cellular, but for the most part the rock is compact. I nowhere found any traces of lapilli or ashes. Some of the numerous streams issuing from the mountain have excavated valleys through the lava to a depth of 200 or 300 feet. One of these streams (the Mariarano), which flows into the Bay of Rodo on the north-east coast (lat. 12° 38′ S.), has cut through the lava-bed and into the underlying rock. Around the base of Ambohitra a goodly number (probably a score or two) of parasitic cones exist, some of which show breached craters, but none of which are in a good state of preservation. One of these (south-west of Ambohitra) I examined very cursorily. Some of the layers on the

[1] [The sandstone fossils alluded to here are from the Antankarana province on the north-western boundary of the central hill-range.—R. B. N.]

[2] Immediately to the south-east of this bay, however, there is a mountain-mass, covering an area of probably 100 square miles, which stands out high above the lava-bed; of this I shall speak by-and-by.

sides of the much-worn cone consisted of breccia, from which I picked out olivine-basalt, augite-andesite (477, the only specimen I met with in this part of the island), and a fine-grained sandstone, which had doubtless been brought up from the underlying strata. It may here be also mentioned that at the village of Ankatoka, in the Antankarana country, south of Ambohitra mountain, there are some hot springs; and about 1½ mile south of the village of Anivorano, at the south-eastern base of Ambohitra, there is what I take to be a crater-lake, known as Tanavo, about a mile in diameter.

The mountain-mass lying immediately south-east of Diego Suarez Bay, referred to on the preceding page, is composed chiefly of reddish and greyish limestone (472, 473) which belongs to the Cretaceous series (probably Upper). In some places (as in the town of Ambohimarina) it assumes the aspect of ruined masonry. The strata appear to have a very slight dip northwards. That part of the mass on which the town of Ambohimarina stands (long. 49° 26′ E., lat. 12° 27′ S.) reaches an elevation of 1400 feet above the sea, and about 800 or 1000 feet above the lava-flooded plain to the south and west. No part of the mountain-mass rises much higher than this. In the limestone I found several specimens of a fossil echinoid, which Mr. R. B. Newton identifies as *Lampadaster Grandidieri*. A microscopic section of the rock in which these occur shows it to be 'largely composed of *Globigerinæ*.' The rock may therefore be called 'a *Globigerina*-limestone.' [R. B. N.] The same section shows other forms of foraminifera, such as *Frondicularia*, *Nodosaria*, *Bulimina* (?), etc.

Evidence of recent elevation of the northern end of the island is to be found in several places. On the low-lying narrow platform adjoining the sea at the base of the mountain-range immediately north of the River Lokia, above mentioned, there are distinct patches of coral-bed, as also rock formed of sand and comminuted sea-shells. Again, at a considerable elevation above the sea, on the island of Nosimitsio (long. 48° 35′ E., lat. 12° 52′ S.), north-west of Madagascar, Mr. Parrett gathered shells which, being compared, were found to be perfectly identical with those lying on the sea-shore. The north-west of the island, as far south at least as lat. 14° 20′ S. (probably much farther), has also been recently raised, as is proved by the existence of numerous sea-shells lying a few miles inland at a height of, at any rate, 100 or 200 feet. Further, in some of the larger vesicles on the surface of the lava-bed east of the mountain of Ambohitra, some 4 or 5 miles south of the town of Ambohimarina, spoken of above, I found the remnants of a kind of oyster-shell still firmly attached. The distance from the present coast-line where these were found was 8 or 10 miles, and the height above sea-level about 300 or 400 feet.

All these facts put together seem to point to the following conclusions in regard to the geology of the northern end of Madagascar:—(1) During some portion or portions or the whole of Jurassic and Cretaceous times this part of the island was beneath the sea. (2) It was afterwards raised, and, judging from the apparent absence of fossils later than Cretaceous, was probably above

the sea during the interval between Cretaceous and recent times. (3) Then came subsidence to the extent at least of submerging the mountain-mass immediately south-east of Diego Suarez Bay and the part now forming the island of Nosimitsio (probably much more). (4) Afterwards elevation once more took place, but in quite recent times, the low-lying country between lat. 12° 45′ S. and this mountain-mass being perhaps excavated (possibly by marine action) during the upheaval, probably leaving the said mountain-mass for a while as an island. (5) During this upheaval (probably the latter part of it) the volcanic activity which brought into existence the mountain of Ambohitra commenced. This seems to be shown by the occurrence of the oyster-shells in the cavities of the lava at the locality above mentioned, which must have been at that time at or below sea-level, but which is now, as before stated, some 300 or 400 feet above it and 8 or 10 miles from the east coast. (6) The maximum of upheaval seems to have been attained in the neighbourhood of Diego Suarez Bay, or immediately south of it; and as the north-western coast appears to have been raised to a greater distance south than the north-eastern, the latter has probably experienced the minimum of upheaval.

North of Diego Suarez Bay there is a triangular headland known as Baobaomby, but of this little seems to be known. So far as I can make out, however, it appears to consist chiefly of limestone, or limestone and sandstone, with a few extinct volcanic cones.

V. The North-west Coast and Islands.

The more or less abrupt western edge of the great central mountain-range of the island is, in the north-west (a little south of lat. 13° and thereabouts), composed chiefly of brownish sandstone, except at the extreme northern portion, where, as has been already stated, it consists mostly of oolitic limestone. This sandstone is generally of coarse texture, containing in places numerous large round pebbles. The western base of this range as far as the sea is mostly occupied by a belt of low-lying land, or, rather, low undulating hills of varying width, and reaching probably nowhere a greater height than 600 or 800 feet, though isolated mountains here and there rise to a considerable elevation above the general level. These mountains sometimes consist of sandstone—for example, Angaraony (long. 48° 12′ E., lat. 14° 20′ S.); sometimes of volcanic rocks, as Bezavona (long. 48° 8′ E., lat. 14° 3′ S.), etc. Angaraony, which reaches an elevation of perhaps 1000 feet above the ground below, with its comparatively horizontal sandstone strata, stands out as a witness to the great erosion which this part of the island has undergone. That the sandstones are of contemporaneous age with the limestones is shown by the fact that in certain localities—for instance, a mile or two south of Andranosamonta (long. 48° 4′ E., lat. 14° 13′ S.)—the limestones lie in beds distinctly intercalated in the sandstones and conformable with these, to

which, nevertheless, they are always subsidiary. The limestones in this locality are very largely composed of lamellibranchiata, such as *Astarte Baroni*, etc.[1] These lie about on the ground (having weathered out from the matrix) in such quantities that they might be literally gathered in cartloads. This frequent alternation of sandstone and limestone would seem to point to a successive rising and falling of the land in this part of the island at the time of their deposition.

Some 4 or 5 miles north of Andranosamonta (300 or 400 feet above the sea and a mile or two from the shore) the limestone, as shown by its fossil contents, belongs to the Oxfordian series, one of the commonest species being *Perisphinctes* (*Ammonites*) *polygyratus*, Reinecke. This lies on the surface of the ground in great numbers, but unfortunately the limestone in which it is embedded has decayed into a mere clay, and thus the fossils are in a bad state of preservation, both they and their matrix being abundantly occupied by septaria filled with calcite. A few miles west of Ankaramy occurs a black crystalline limestone, which, according to Mr. R. B. Newton, contains an organism called *Girvanella*. At Andranosamonta itself I was fortunate enough to find parts of the first fossil reptile that has been discovered in the island. It proves to be a new species of *Steneosaurus*, which Mr. R. B. Newton has named *S. Baroni*.[2] It may be noted that immediately north of this village selenite occurs in the clay.

This belt of low-lying land on the north-western coast consists therefore mostly of sandstone, though limestone is also abundant, the predominant dip of both being very slightly seawards. The sandstone is mostly of medium grain and brownish colour, and generally turns red in weathering. In some places spherical or oval nodules, about the size of a hen's egg, of ferruginous matter which has probably segregated from the surrounding mass, jut out from the exposed surface of the rock. Fossils gathered from the limestone show it to be mostly Jurassic, but occasionally Cretaceous (Neocomian), and on the coast-line mainly Eocene (Nummulitic Limestone). That this portion of the island has been recently elevated above the sea to the extent of at least 200 or 300 feet has been already stated; to this I need not therefore again recur.

In Quart. Journ. Geol. Soc. vol. xlv. (1889), pp. 326, 327, I spoke of some strange rocks resembling erratic blocks lying on the surface of the ground in the neighbourhood of the village of Mahitsihazo (long. 48° 5′ E., lat. 14° 17′ S.), whose existence I could not then account for, suggesting, with a good deal of doubt, that they had been possibly brought there by glacial action. The difficulty of accounting for their occurrence is now solved. I find from microscopical examination that these rocks are trachyte. But how came the blocks into their present position? The explanation is simple. Nearly the whole of this low-lying land, from the village

[1] See Mr. R. B. Newton's paper (p. 78) for names of other fossils found here.

[2] Geol. Mag. 1893, pp. 193–196, pl. ix.

of Melaka (long. 48° 18′ E., lat. 13° 45′ S.) to that of Mahitsihazo, was once flooded with trachytic lava, which has since been largely denuded, leaving patches, sometimes many square miles in extent, in various places, thus allowing the underlying sandstones and limestones to reappear at the surface. In other places mere blocks of rock, some of them as large as small cottages, are the only remnants left of the lava-bed, but those immediately north of Mahitsihazo have apparently rolled down from a higher level. The curiously and deeply guttered appearance of these latter blocks is probably due to the action of rain alone. The trachyte varies in texture from fine to coarse-grained, and in colour from buff or brownish to whitish. It is in places decayed and altered into clay, and is often somewhat fissile. Not infrequently it has weathered into small cuboidal blocks of an inch or two in diameter, the interstices being filled in with ferruginous matter, the blocks often becoming detached one from the other and covering the ground. Passing through the country in one direction only, I failed to gather sufficient data as to the direction of the lava-flow to indicate its source.

A mountain named Bezavona (long. 48° 8′ E., lat. 13° 55′ S.), probably not less than 1200 feet high, is specially worthy of mention from the fact that it consists of the comparatively rare rock foyaite (491), the mineral with low double refraction proving to be nepheline. In long. 48° 8′ E., lat. 14° 3′ S., there is a hill (some 10 or 12 miles south of Bezavona) known as Ankitsika or Ambohibainga, probably 700 or 800 feet high. The rock is here also volcanic, but in this case it is nepheline-phonolite (292, 294).[1] Not far from the hill of Ankitsika (some 5 or 6 miles north-north-west of it) occurs an interesting form of haüyne-nepheline-phonolite with well-formed crystals of melanite (268, 314, etc.). There seems to have been little, if any, actual outflow of lava from Ankitsika mountain. It is of interest to note the existence of foyaite, nepheline-phonolite, and haüyne-nepheline-phonolite in such close association.

The narrow promontory running north, which lies on the line of long. 48° E., and forms the gulf (Port Radama in some maps) at the head of which is the village of Andranosamonta, is chiefly composed of basalt, being olivine-basalt (282) on its eastern edge, and basalt without or with but little olivine on its western edge (254). In one locality (about halfway along the length of the promontory on its eastern side) I found in the basalt large nests of beautifully striped onyx and multicoloured Egyptian jasper. On the western side very large nodules of green chalcedony (237) occur in the basalt. In the olivine-basalt of the small island of Ankazoberavy, south-west of the large island of Nosibe, Egyptian jasper, banded in various colours and of rare beauty, is found.

Immediately south-west of Anorontsanga (long. 47° 58′ E., lat. 13° 50′ S.) there are four islands (excluding islets of little

[1] Possibly some of the trachyte mentioned above may prove on further examination to be nepheline-phonolite.

note): Ambariovaliha, Berofia, Kalakajoro, and Antanifaly. The first three of these are volcanic, and are composed wholly of olivine-basalt similar to that above mentioned (256, 504). The rock is remarkable for the abundance of amygdules or nests of segregated minerals which it contains. These amygdules are generally of large size, often attaining to a diameter of a couple of feet. They are frequently hollow within (geodes), and consist for the most part of pure crystalline quartz, but sometimes of agate, onyx, or green (237) or brown chalcedony (501). Occasionally well-crystallized calcite, generally whitish, sometimes olive-green, accompanies the quartz, and is also often found filling fissures in the rock.

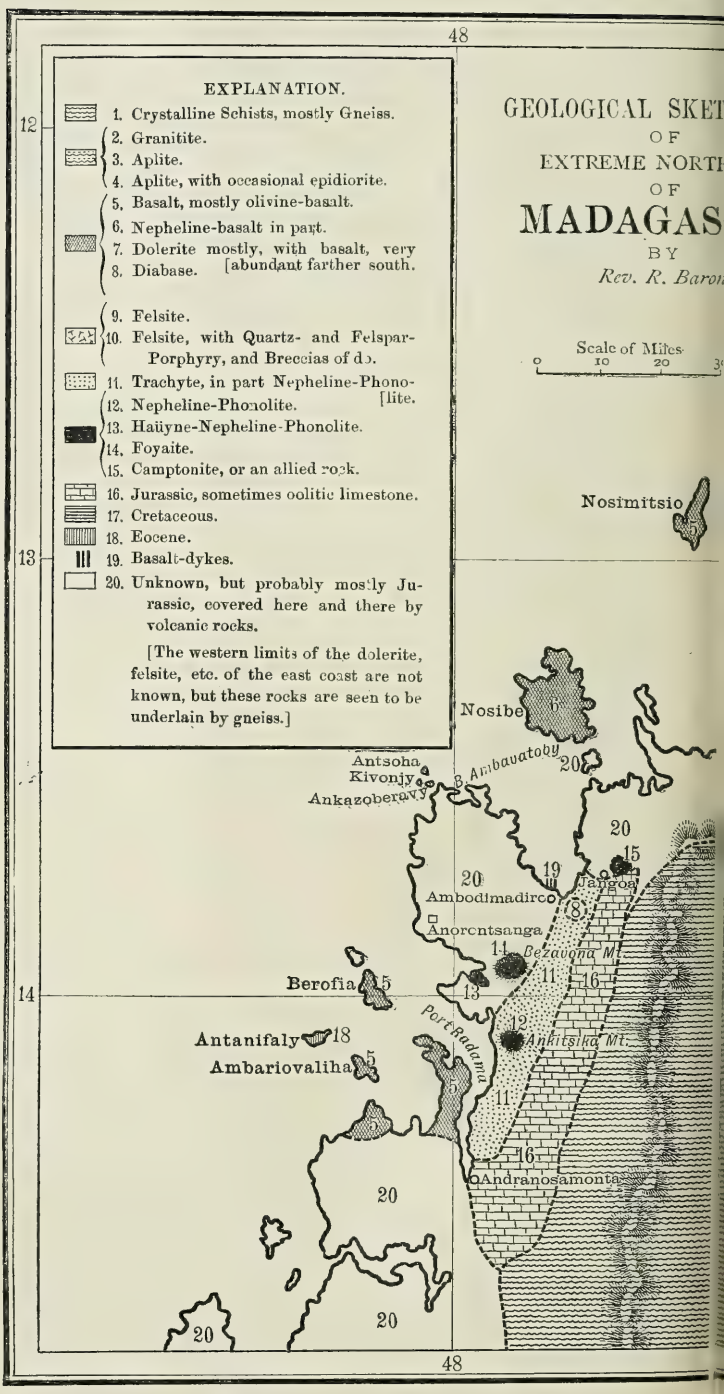
The island of Antanifaly, however, which is the westernmost of the group, consists entirely of Nummulitic Limestone, in which *Assilina spira*, de Roissy, and several species of *Nummulites* (see Mr. R. B. Newton's paper) are the commonest fossils. About 30 miles or so north of these islands (lat. 13° 30′ S.) there are three islets near the mainland: Kivonjy, Antsoha, and Ankazoberavy, the last two, and probably also the first, being volcanic, the rock again being olivine-basalt, which on Antsoha is columnar, the columns, however, being much bent and irregular. Kivonjy is a round beehive-shaped islet, the rock of which, from a distance, has a whitish colour. It may possibly be trachyte.

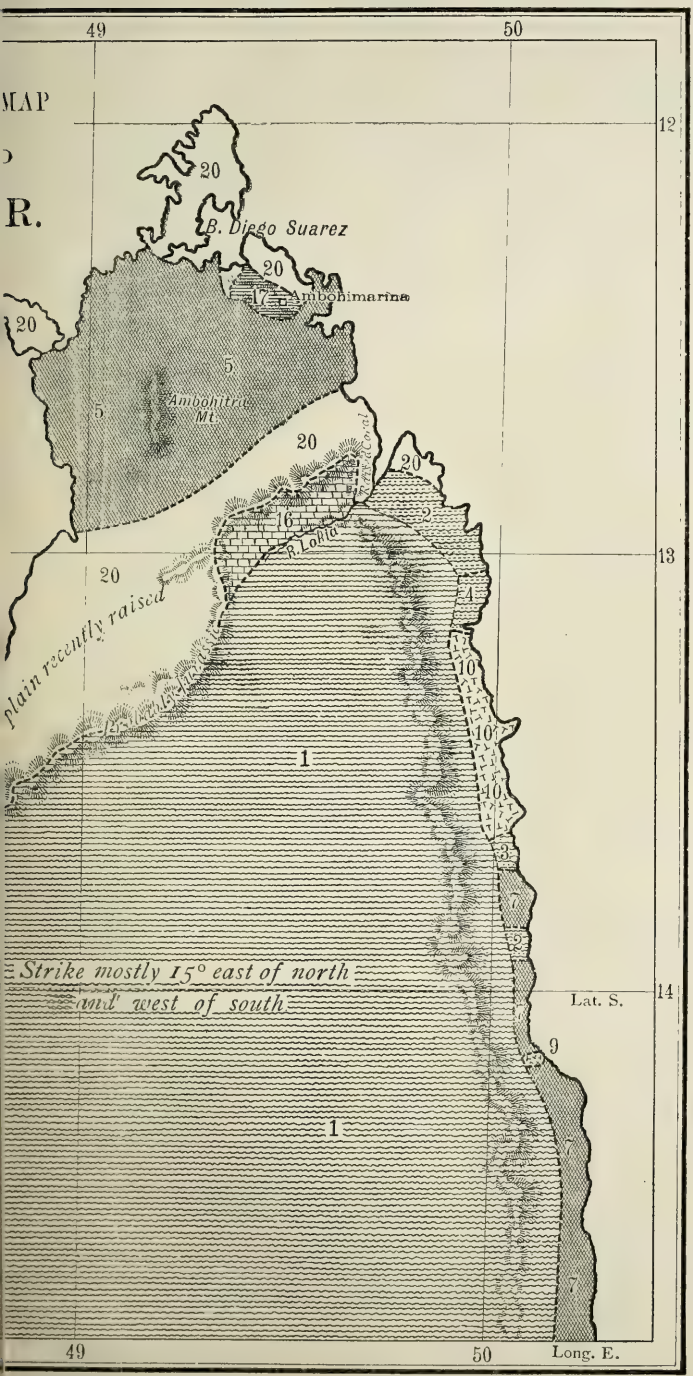
Farther north again is the large island of Nosibe, which is in the possession of the French. This island is for the greater part dotted over with volcanic cones of no great height, which are in a fair state of preservation. There are two fine crater-lakes on its southern edge. The only specimen of the rock which I gathered from this island proves to be nepheline-basalt (265).

Another island, Nosimitsio, farther north again (long. 48° 35′ E., lat. 12° 52′ S.), which, however, I have not seen, is also volcanic. On the east coast of this island there are said to be some fine exposures of columnar basalt, and, as was mentioned before, shells have been here gathered at a height of 200 or 300 feet exactly corresponding to those lying on the shore.

Thus we see that, while trachytic and phonolitic lava has been poured out in great quantity in the north-western part of Madagascar, basaltic lava has been erupted in equal, if not even in greater measure; and that, while trachyte seems to be confined to the mainland not far from the sea, basalt occupies parts of the coast-line of the same, and apparently forms, with the one exception already mentioned, all the islands in the region. Basalt is not, however, entirely absent several miles inland, as it may be picked out of the beds of some of the rivers immediately below the western declivity of the central mountain-chain, as, for instance, close to the village of Ankaramy, about 20 miles from the coast.

On the sea-coast at Ambodimadiro (long. 48° 14′ E., lat. 13° 37′ S.) a goodly number of dykes of a rather anomalous basalt make their appearance (see description by Dr. Hatch in Quart. Journ. Geol. Soc. vol. xlv. 1889, p. 345), reminding one of those


48
12
13
14
EXPLANATION.
1. Crystalline Schists, mostly Gneiss.
2. Granitite.
3. Aplite.
4. Aplite, with occasional epidiorite.
5. Basalt, mostly olivine-basalt.
6. Nepheline-basalt in part.
7. Dolerite mostly, with basalt, very
8. Diabase. [abundant farther south.
9. Felsite.
10. Felsite, with Quartz- and Felspar-Porphyry, and Breccias of do.
11. Trachyte, in part Nepheline-Phono-
12. Nepheline-Phonolite. [lite.
13. Haüyne-Nepheline-Phonolite.
14. Foyaite.
15. Camptonite, or an allied rock.
16. Jurassic, sometimes oolitic limestone.
17. Cretaceous.
18. Eocene.
19. Basalt-dykes.
20. Unknown, but probably mostly Jurassic, covered here and there by volcanic rocks.
[The western limits of the dolerite, felsite, etc. of the east coast are not known, but these rocks are seen to be underlain by gneiss.]
GEOLOGICAL SKET
OF
EXTREME NORTH
OF
MADAGAS
BY
Rev. R. Baron
Scale of Miles
0 10 20
Nosimitsio
Nosibe
Antsoha
Kivonjy
Ankazoberavy
Anbavatoby
Ambodimadirco
Anorontsanga
Bezavona Mt.
Tangoa
Berofia
Antanifaly
Ambariovaliha
Port Radama
Ankitsika Mt.
Andranosamonta
48



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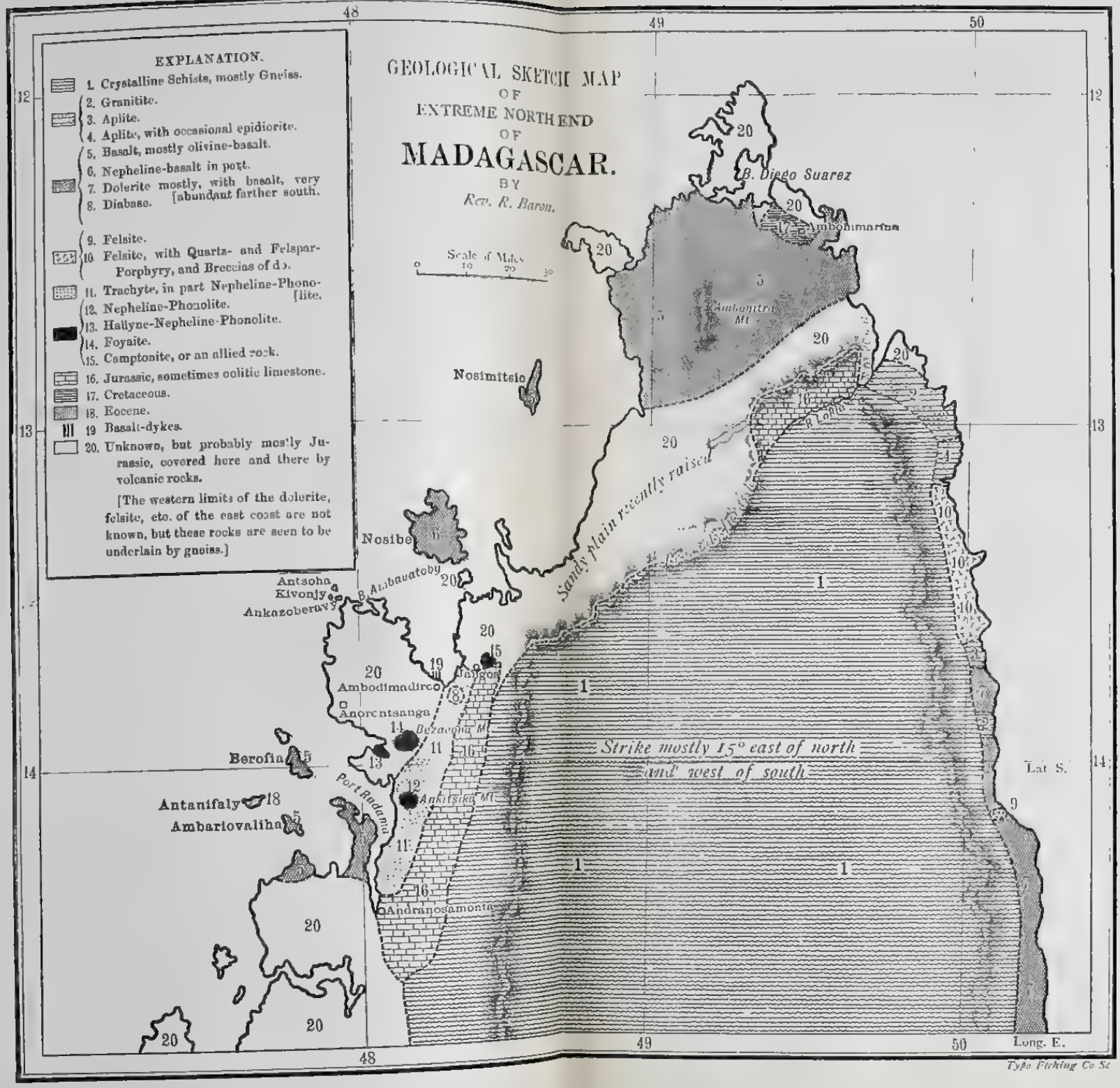

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on the sea-shore near Belfast in the north of Ireland. Here it may be mentioned also that an interesting rock allied to Rosenbusch's camptonite, together with an andesite, occurs east of the village of Jangoa (long. 48° 19′ E., lat. 13° 40′ S.).

We see, therefore, that in this north-western part of Madagascar both intermediate and basic lavas occur, consisting of trachyte, phonolite, haüyne-nepheline-phonolite, andesite (rare), basalt, and olivine-basalt.

At Ambavatoby, a small bay on the mainland south-west of the island of Nosibe, coal of excellent quality is said to have been obtained (see 'Annales des Mines,' 1854, 1856, 1866). I visited all the points in this bay where coal is said to exist, and could find nothing but thin seams of carbonaceous shale intercalated among (Jurassic?) sandstones. What there may be below the surface I cannot of course say, but am strongly inclined to doubt altogether the existence of coal. This carbonaceous shale, it may be mentioned, occurs at several points on the roundish headland south of Nosibe.

Such is a brief account of some of the more salient features in the geology of those parts of Madagascar traversed during my journey, and I trust that, in spite of its imperfection, this account will not be found altogether devoid of interest from the geological point of view.

Perhaps I may be allowed here to make one or two slight alterations and corrections of my former paper entitled 'Notes on the Geology of Madagascar,' Quart. Journ. Geol. Soc. vol. xlv. (1889).

P. 308,—*In first paragraph under* 'Crystalline Schists, etc.' *instead of* 'For instance....60 or 80 miles,' *read*: 'For instance, a large area in the interior, reaching from about the capital to at least 100 miles north of it, and probably 60 or 80 miles in width, consists of gneiss with the strike of the foliation running generally in a north-westerly or north-north-westerly and south-east or south-south-easterly direction, or approximately thereto.'

P. 311, lines 9 and 10 from top.—*For* 'It is a reddish rock.... decayed gneiss,' *substitute*: 'This rock may be described as sillimanite-schist, being composed of sillimanite and quartz, with abundant almandine-garnet, by the presence of which the rock is coloured red.'

On map.—*For* 'bosses of diorite?' *read* 'cones of nepheline-phonolite.'

EXPLANATION OF PLATE I.

Geological Sketch-map of the extreme north end of Madagascar.

Scale: 1 inch = 30 miles.

[For the Discussion on this paper, see p. 92.]

8. *On a* Collection *of* Fossils *from* Madagascar *obtained by the Rev. R. Baron.* By R. Bullen Newton, Esq., F.G.S., of the Geological Department, British Museum [Natural History]. (Read November 21st, 1894.)

[Plates II. & III.]

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I. Introduction.

The fossils contained in this collection were procured from a number of localities in the northern and north-western parts of Madagascar by the Rev. R. Baron, during an extensive journey which he undertook in 1891, as an officer of the London Missionary Society. They may be regarded as supplemental to those that he collected some few years previously in the north-western districts, fossils which were described in 1889 before this Society as representative of Eocene, Cretaceous, and Jurassic rocks.

The present collection, besides comprising organic remains from these different horizons, contains a few terrestrial shells referred to *Achatina panthera*, *Achatina* like *A. Layardi*, *Buliminus* (*Rachis*) *punctatus*, and *Pomatias* (*Tropidophora*) *virgata*. These were found in a Quaternary deposit capping the hill of Ambohimarina at a height of over 1400 feet above sea-level, and they are known to exist on the island at the present day. The Tertiary (Eocene) specimens consist entirely of foraminifera. They were obtained from the island of Antanifaly (N.W. coast) and have been determined as *Nummulites* allied to *N. Bellardii*, *N. perforata*, *N. complanata*, and *Assilina spira* ; species which have a wide distribution, though mostly confined to South European countries, Egypt, West Asian localities, and India.

The Cretaceous fauna contributes one specimen of *Lampadaster Grandidieri* ?, found in a red limestone, immediately beneath the subsoil of Ambohimarina Hill, which also contains *Frondicularia*, etc., and dense masses of *Globigerinæ* ; while examples of *Belemnites pistilliformis* prove the presence of Neocomian rocks north of Andranosamonta village.

Among Jurassic fossils a new species of gasteropod has been described, besides several lamellibranchs ; while a form of *Perna* with extremely antero-convex valves has been doubtfully referred to a Syrian species. In studying the Jurassic fauna of Madagascar one is struck with its resemblance to that of England, Europe, Eastern Africa, and India. Such forms as *Trigonia pullus* and

T. costata occur in all these regions, *Ceromya concentrica* and *Modiola imbricata* are recorded from Eastern Africa and Madagascar, while *Stephanoceras Herveyi*, *Corbula pectinata*, and *Rhynchonella concinna* are found alike in Madagascar and India. The Jurassic rocks of Eastern Africa extend from Abyssinia,[1] through Shoa, Mombassa, Mtaru to Mozambique, at which latter locality Beyrich[2] has reported the discovery of a *Phylloceras* (allied to) *heterophyllum*, a species also found in Madagascar.

Several cephalopods have been described from East African localities by Beyrich,[3] Douvillé,[4] Tornquist,[5] and Futterer,[6] many of them being referred to Indian forms, and the correlation-tables given by the last-named author prove very conclusively that a close relationship exists between these widely separated Jurassic regions.

In completing my work on the fossils shortly to be described I wish to record my obligations to the following specialists for their kindly assistance and advice:—To the late M. Gustave Cotteau for identifying the Cretaceous echinoid; to Prof. T. Rupert Jones, Dr. G. J. Hinde, Mr. E. Wethered, Mr. E. T. Newton, and Mr. W. W. Watts for their help in identifying the limestone-structures; to Mr. G. C. Crick for suggestions regarding the cephalopods; and to Mr. Edgar Smith for examining the post-Tertiary mollusca.

It is important to note that Mr. Baron, following up a former precedent in connexion with his first series of Malagasy fossils, has most generously given the present collection to the Geological Department of the British Museum.

II. Previous Work on the Palæontology of Madagascar.[7]

The earliest record bearing upon this subject is by Buckland, who in September, 1821, described a rock of Secondary age from Point Lougi or Loquez, on the north-eastern coast, somewhat resembling New Red Sandstone, but containing no organic remains. The recent limestone-formations occurring round the coast-line of Madagascar were also referred to as being "composed of granulated fragments of shells agglutinated by a calcareous cement," the shells being too broken to allow of their determination.

Later in the same year, James Sowerby[9] described *Isocardia minima* from the English Cornbrash, and stated that he had "similar ones from Madagascar." This would form the first reference to a recognized fossil mollusc from that country.

[1] W. T. Blanford, 'Observations on the Geology and Zoology of Abyssinia,' 1870, pl. viii. pp. 176–180, 199–203.

[2] Monatsb. k. preuss. Akad. Wissensch. Berlin, 1877, p. 765.

[3] *Ibid.* pp. 96–103.

[4] Bull. Soc. géol. France, ser. 3, vol. xiv. (1886) pl. xii. p. 223.

[5] Jahrb. d. hamburgisch. naturw. Gesellsch. 1893, vol. x. pt. ii. 3 plates, pp. 265–288.

[6] Zeitschr. deutsch. geol. Gesellsch. vol. xlvi. (1894) pls. i.–vi. pp. 1–49.

[7] Excluding references to Quaternary vertebrata.

[8] 'Notice on the Geological Structure of a part of the Island of Madagascar,' Trans. Geol. Soc. ser. 1, vol. v. (1821) p. 479.

[9] 'Mineral Conchology,' vol. iii. (1821) p. 171.

During 1854 an anonymous author[1] reported the discovery, by some French naval officers, of lignite-deposits containing plant-impressions on the Island of Nossi-Bé and at neighbouring localities in the north-west. These deposits were stated to be of, probably, Secondary age.

In the following year Herland[2] called attention to a recent limestone with *Nummulites* which he had found bordering parts of the coast-line of Nossi-Bé, during his survey of that island.

M. Guillemin[3] in 1866 described very fully the coal-districts in the north-west, but made no allusion to the presence of fossils, and therefore no statement as to the age of the beds. The occurrence of Secondary fossils in the southern parts of the island was announced by M. Grandidier[4] in 1867, and one of the specimens was described in the succeeding year by the late Paul Fischer[5] as a Jurassic species, under the name of *Nerinæa leiogyra*.

MM. Crosse and Fischer[6] during the same year noticed some terrestrial shells of Quaternary age which had been collected by M. Grandidier near Cape Ste. Marie, in the extreme south. They were found associated with *Æpyornis*-remains in the sand-dunes which here rise to a height of 142 metres (466 feet), the species being closely allied to those existing on the island at the present time. They were determined as *Buliminus Grandidieri*, C. & F., *B. subobtusatus*, C. & F., *B. Favannei*, Lamarck, *Helix*, sp., and *Cyclostoma* (*Otopoma* ?) *Grandidieri*, C. & F.

M. Grandidier,[7] in 1871, mentions that he had, during 1865 and 1866, collected fossils belonging to the Carboniferous epoch on the north-western coast at the Bay of Passandava, but states that they were accidentally destroyed by fire, together with his notes, sketches, and other valuable data made during that period. [The nature of these fossils is not stated; they probably consisted of plant-remains from the lignite-deposits which have been regarded as of Secondary age.]

The first reliable proofs of an Eocene fauna were obtained by M. Grandidier from near St. Augustine's Bay, on the south-western coast, and the specimens were identified by Fischer[8] in 1871 as

Alveolina (like) *ovoidea*, d'Orbigny, or *subpyrenaica*, Leymerie.
„ *longa*, Czjzek.

[1] 'Découverte de Lignite à Nossi-Bé et sur la côte occidentale de Madagascar,' Annales des Mines, ser. 5, vol. vi. (1854) pp. 570–576.

[2] 'Essai sur la Géologie de Nossi-Bé,' Annales des Mines, ser. 5, vol. viii. (1855) p. 335, pl. v. (map).

[3] 'Notice sur une Exploration géologique à Madagascar pendant l'année 1863,' Annales des Mines, ser. 6, vol. x. (1866) p. 277.

[4] 'Notice sur les Côtes sud et sud-ouest de Madagascar,' Bull. Soc. Géographie, ser. 5, vol. xiv. (1867) pp. 384–395.

[5] 'Note sur la Géologie du sud de Madagascar,' Bull. Soc. géol. France, vol. xxv. (1868) p. 398 (not figured).

[6] 'Note sur quelques espèces nouvelles de Madagascar recueillies à l'état fossile,' Journ. Conchyl. (Paris) vol. xvi. (1868) pp. 180–187, pl. vii. figs. 1–3.

[7] 'Madagascar,' Bull. Soc. Géogr. ser. 6, vol. ii. (1871) p. 88.

[8] 'Sur l'existence du terrain tertiaire inférieur à Madagascar,' Comptes-rendus Acad. Sci. Paris, vol. lxxiii. (1871) p. 1392 (no figures given).

Orbitoides (like) *papyracea*, Boubée.
Triloculina (like) *trigonula*, d'Orbigny.
Ostrea pelecydion, Fischer,
like *O. Villei*, Coquand, or *Perna Mulleti*, Deshayes.
Ostrea Grandidieri, Fischer.
Neritina Schmideliana, Chemnitz.
Terebellum (like) *obtusum*, J. de C. Sowerby.

In 1872 M. Grandidier [1] noticed the enormous development of Jurassic rocks in Madagascar (overlain in parts by a narrow band of Nummulitic limestone containing *Neritina Schmideliana*, *Alveolina*, etc.), which was stated to extend from the southern border of the Bay of Narrinda to the western slope of the granitic mountains protecting Fort Dauphin (south-east corner).

Fischer [2] described another series of fossils in 1873, collected by M. Grandidier from the Jurassic rocks of Tulléar and Morundava in the south-western portion of the island. His determinations and horizons were as follows :—

Nerinæa leiogyra, Fischer.
Natica (near to) *Clio*, d'Orb. [Oxfordian].
„ „ *canaliculata*, Morris & Lycett [Great Oolite].
„ *dubia*, Römer [Kimeridge].
Solarium (near to) *polygonum*, d'Archiac [Great Oolite].
Trochus (near to) *Ibbetsoni*, Morris [Great Oolite].
Cerithium eribote, d'Orb. [Oxfordian].
„ (like) *russiense*, d'Orb. [Oxfordian].
Alaria, sp.
Rhyncholites (like) *gigantea*, d'Orb. [Oxfordian].
Ammonites fimbriatus, J. Sowerby [Lias].
„ (group) *heterophyllus*, J. Sowerby [Lias].
„ „ *Parkinsoni*, J. Sowerby [Inferior Oolite].
Astarte excavata, J. Sowerby [Inferior Oolite].
„ (group) *depressa*, Münster [Oxfordian].
„ „ *minima*, Phillips [Great Oolite].
„ „ *phyllis*, d'Orb. [Oxfordian].
„ „ *alta*, Goldfuss [Lias].
Rhynchonella tetrahedra, J. Sowerby [Lias and Inferior Oolite].
„ *concinna*, J. Sowerby [Great Oolite].

M. de Fromentel determined the corals as :—

Montlivaltia trochoides, M.-Edw. & Haime [Inferior Oolite].
Epismilia Grandidieri, n. sp. } [No horizons given,
Isastræa Fischeri, n. sp. } but probably Lias].

In 1877 the Rev. J. Richardson,[3] of the London Missionary Society, published details of his journey through the southern districts of Madagascar. In the vicinity of Aborano he collected some well-preserved Secondary fossils of Jurassic age [wrongly referred to the Neocomian by the Rev. James Sibree [4]], which were figured, to

[1] 'Madagascar,' Bull. Soc. Géogr. ser. 6, vol. iii. (1872) p. 369.
[2] 'Sur le terrain jurassique de Madagascar,' Comptes-rendus Acad. Sci. Paris, vol. lxxvi. (1873) p. 111 (no figures given).
[3] 'Lights and Shadows: or Chequered Experiences among some of the Heathen Tribes of Madagascar,' 1877. Plate [fossils] and route-map [Antananarivo]. 8vo. The fossils are referred to on pp. 38 and 68.
[4] 'Observations on the Physical Geography and Geology of Madagascar,' 'Nature,' vol. xx. (1879) pp. 368–372.

form the plate accompanying his pamphlet, but without names or descriptions. These figures represent an echinoid and an ammonite, both subsequently described and re-figured by the present writer [1] as *Stomechinus* (allied to) *bigranularis*, Lamarck and *Stephanoceras Herveyi*, Sowerby, respectively; a *Nerinæa*; a *Rhynchonella*; a *Terebratula*; and two lamellibranch shells. This plate is of great interest, for it contains the first published illustrations of a Jurassic fauna from Madagascar, and I am indebted to the Rev. George Cousins for calling my attention to it. The Rev. R. Baron [2] in 1885 recorded the occurrence of an extinct form of *Equisetum* in a siliceous sinter-deposit or geyserite which he found in one of the valleys close to some extinct volcanic craters, near Ambòhidratrimo (north of Antananarivo). He also mentions the finding of numerous fragments of fossil plants in an ironstone-and-shale deposit on the plain of Ankay (Central Madagascar), one being recognized as *Calophyllum parviflorum*, Bojer (a dicotyledonous plant).

In 1887 Cortese [3] referred to a lignite-deposit in the neighbourhood of Amparihibé (Betsiboka river) which he regarded as of Pliocene age, but the lignites of Nossi-Bé and the neighbouring region he [4] identified as doubtfully of Permo-Carboniferous age in the succeeding year.

In 1889 I reported [5] upon a collection of fossils obtained by the Rev. R. Baron from various localities in the north-west, and included in it some references to a few specimens belonging to the Rev. Dr. Deane, which were collected by the Rev. J. Richardson in the south. Two of these latter specimens were figured, as previously mentioned, in Mr. Richardson's plate published in 1877. An examination of Messrs. Baron and Richardson's fossils confirmed the work of previous observers as to the existence of Eocene and Jurassic rocks in Madagascar, while a Cretaceous fauna was apparently identified for the first time.

The Eocene fossils consisted principally of foraminifera, referred to *Alveolina oblonga*, *Nummulites biarritzensis*, *Assilina spira*, etc.

The Cretaceous included such forms as *Nautilus Fittoni*, *Belemnites pistilliformis*, *B. conicus*, *B. polygonalis*, *B. binervius*, *Alectryonia ungulata*, *A. pectinata*, *A. Deshayesi*?, *Gryphæa vesicularis*, etc.

The Jurassic rocks were represented by *Stephanoceras Herveyi*, *Belemnites Sauvanausus*, *Nerita Buvignieri*, *Nerinæa* (allied to) *Eudesi*, *Pteroperna costatula*, *Modiola imbricata*, *Pholadomya ambigua*, *Ceromya concentrica*, *Astarte* (?) *Baroni* (n. sp.), *Sphæra madagascariensis* (n. sp.), *Terebratula maxillata*, *Rhynchonella obsoleta*, *Stomechinus* (allied to) *bigranularis*, *Isastræa*, etc.

[1] 'Notes on Fossils from Madagascar, with Descriptions of two New Species of Jurassic Pelecypoda from that Island,' Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 334, 338, pl. xiv. figs. 1, 2, 13–15.

[2] 'Notes on the Geology of the Interior of Madagascar,' Antananarivo Annual for 1885, no. ix. pp. 59–77.

[3] 'Osservazioni geognostiche sul Madagascar,' Boll. R. Comit. geol. Italia, vol. xviii. (1887) p. 187.

[4] 'Appunti geologici sull' Isola di Madagascar,' *op. cit.* vol. xix. (1888) pp. 113 & 123.

[5] R. B. Newton, *op. jam cit.*

Later in the same year (1889) M. Gustave Cotteau[1] described, but without figuring, two Cretaceous echinoids collected by Colonel Rocard at Antsingy, south of the Bay of Diego Suarez, in the extreme north of the island.

These were determined as *Guettaria Rocardi* (n. sp.) and *Lampadaster* (n. gen.) *Grandidieri* (n. sp.).

Early in 1890, the late Prof. Neumayer[2] summarized the more important results which he considered deducible from the determinations of Mr. Baron's fossils made by myself in the previous year. He instituted a comparison between the Uitenhage (Neocomian) formation of South Africa and the Neocomian beds of Madagascar, taking the *Belemnites* for his palæontological standard. The only species of this cephalopod occurring in the former is *B. africanus*, referred to the group *Absoluti*, which is typical of the boreal region and the northern part of the temperate zone.

The belemnites of Madagascar are represented by the groups *Hastati*, containing *B. pistilliformis*; and *Notocœli*, containing *B. conicus*, *B. polygonalis*, and *B. binervius*; both of which groups include typically equatorial forms, and, though widely distributed in Middle European regions, do not occur in northern territories or in boreal areas. This evidence was regarded, together with other details, as demonstrating the existence of land in Cretaceous times extending from South Africa across the Indian Ocean. The whole of this subject was subsequently enlarged upon in Dr. W. T. Blanford's[3] Presidential Address before the Geological Society during the same year.

A list of the known fossils from Madagascar was published by Mr. Baron[4] in 1890. One hundred and five species were enumerated, with their horizons and localities.

In April 1893 M. Gautier[5] directed attention to the occurrence of *Alectryonia* (*Ostrea*) *ungulata* at Mahamavo (lat. 15° 30′ 45″ S., long. 44° 10′ 50″ E.) in the north-west, and alluded to the rocks containing them as of Jurassic age, specifying the strata on a map which accompanied his remarks. This was an error of judgment, as the species referred to was typically Cretaceous.

In May 1893, I described[6] the first recorded Secondary reptile from Madagascar. This interesting specimen was discovered by Mr. Baron at Andranosamonta village, in the north-west, and from its association with certain forms of molluscan remains (to be after-

[1] 'Échinides crétacés de Madagascar,' Bull. Soc. zool. France, vol. xiv. (1889) pp. 87–89.

[2] 'Ueber neuere Versteinerungsfunde auf Madagascar,' Neues Jahrb. 1890, vol. i. pp. 1–9.

[3] Quart. Journ. Geol. Soc. vol. xlvi. (1890) *Proc.* p. 98.

[4] 'Geological Notes: a complete List of the Known Fossils from Madagascar,' Antananarivo Annual for 1890, no. xiv. pp. 242–245.

[5] 'Mission Émile Gautier à Madagascar,' Annales de Géographie, (Paris) 1893, no. 7, pp. 355–364; map (partly geological).

[6] 'On the Discovery of a Secondary Reptile in Madagascar, *Steneosaurus Baroni* (n. sp.),' Geol. Mag. 1893, pl. ix. pp. 193–196; reprinted in the Antananarivo Annual for 1893, no. xvii. pp. 26–28.

wards alluded to) was judged to be of Lower Oolitic age. This new species was named *Steneosaurus Baroni*.

Subsequently, in the same year, M. Stanislas Meunier[1] determined some Cretaceous oysters collected by M. Gautier at Mahamavo as *Ostrea frons* [=*O. pectinata*], *Ostrea santoniensis* [=*O. Deshayesi*], both of Sénonien age; and *Ostrea columba* [should be *Gryphæa vesicularis*], of Cénomanien age. These species were well illustrated by figures of the natural size.

M. Meunier refers in the same communication to the occurrence of Inferior Oolitic lamellibranchs at Belalitra (west of Mojanga, lat. 15° 40′ S., long. 45° 20′ E.), resembling *Modiola*; to the finding of Jurassic specimens of somewhat different horizon at Andranomena (lat. 14° 15′ S., long. 45° 26′ 10″ E.) representing *Natica*, *Pinna*, *Astarte*, and *Rhynchonella*; and to the discovery of Dinosaurian relics at a place called Motety.

Finally, Mr. J. T. Last,[2] in a popular newspaper article, mentions that he has collected in the northern part of Madagascar (at a spot about 20 miles east of the Bay of Narrinda) the remains of a gigantic Dinosaur, which are now located in the British Museum.

III. Description of the Jurassic Fossils.

Cephalopoda.

Belemnites hastatus, Blainville.

Horizon.—Oxfordian. *Loc.*—Andranosamonta village, landing-place.

[England, Southern Europe, and India.]

Belemnites Sauvanausus, d'Orbigny.

Horizon.—Oxfordian. *Loc.*—Andranosamonta village, landing-place.

[France.]

This species has been previously recorded[3] from the same neighbourhood.

Perisphinctes, sp. (probably allied to *polygyratus*, Reinecke).

This is a fragment of the body-whorl of a large specimen, in which the sutural characters are not sufficiently exhibited for specific determination.

Laterally there are five distant and coarse primary ribs, from each of which proceeds a kind of double bifurcation bearing four finer ribs, and these pass over the dorsal part of the shell without interruption. Involution occupies about one half of the surface of

[1] 'Fossiles Malagaches,' in 'Le Naturaliste' for 1893 (August), ser. 2, no. 154, pp. 175, 176 [with five illustrations].

[2] 'The Hot Springs of Madagascar,' in 'The Field' for May 26th, 1894, vol. lxxxiii. p. 767.

[3] R. B. Newton, Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 334.

the whorl. This fragment most probably belongs to one of the Indian forms described by Waagen.

Horizon.—Jurassic (probably Kimeridgian).

Loc.—North of Andranosamonta.

Gasteropoda.

[Internal cast of a Patelloid shell.]

Horizon.—Lower Oolite. *Loc.*—3 miles north of Iraony.

[A Naticoid shell.]

Horizon.—Lower Oolite. *Loc.*—About 3 miles north of Iraony.

Natica, sp. [Casts.]

Horizon.—Lower Oolite. *Loc.*—About 10 miles S.E. of Andranosamonta village.

Eulima ? sp.

This is a sandstone-impression of a small specimen, probably referable to this genus; it was found associated with *Astarte depressa*, *Pteroperna costatula*, and *Trigonia pullus*.

Horizon.—Oolite (Lower?). *Loc.*—Antankarana province, north-western boundary of the central hill-range.

According to Mr. Baron, the sandstones containing this shell are largely developed in this region, but fossils are rare.

Trochactæonina Richardsoni, sp. nov. (Pl. II. figs. 1–3.)

Shell subcylindrical, ventricose, sides compressed; vertex wide, depressed, containing about five whorls definitely canaliculated at their sutures; the three earliest volutions form a mammillation which stands just above the level of the vertex, apex absent; whorls with rounded margins; columella-border oblique, excavated at the base, without plications, but covered with a thick spreading callosity; mouth elongate and narrow, outer lip thin; surface ornamented with longitudinally curved lines of growth.

Dimensions.—Length = 50 mm.; maximum breadth = 35 mm.; diameter of vertex = 33 × 30 mm.

This specimen is referred to Meek's genus *Trochactæonina*[1] [type *Actæonina ventricosa*, d'Orbigny[2]], which differs from the true *Actæonina* on account of its large ventricose body-whorl and depressed spire.

The other closely allied genera are *Cylindrites*, with a twisted columella, and *Actæonella*, distinguished by its prominent columellar plications. The present shell is recognized as a new species because of its large size, depressed spiral area, and compressed sides. The name of *Trochactæonina Richardsoni* is proposed for it, in honour of the Rev. J. Richardson, of the London Missionary Society, to

[1] Am. Journ. Sci. ser. 2, vol. xxxv. (1863) p. 91.

[2] 'Pal. Française: Terr. jurassiques—Gastéropodes,' 1850, p. 178, pl. cclxxxviii. figs. 7, 8.

whom we are indebted for the earliest published figures of Jurassic fossils from Madagascar.

Horizon.—Oolite (probably Lower), from the same rocks as those which contain *Steneosaurus Baroni*.

Loc.—Andranosamonta village.

Lamellibranchiata.

PERNA ORIENTALIS?, C. E. Hamlin.[1] (Pl. II. figs. 4, 5.)

So far as can be judged from the figures and description of this species from Syria, Mr. Baron's specimens appear to have somewhat similar characters. The sinuated anterior margin, the oblique hinge-line, and the strong anterior convexity of the valves are prominent features of this shell. Unfortunately the hinge-areas of the Malagasy shells are somewhat obscure, so that it is difficult to trace the extensive series of ligamental characters so typical of the Syrian form; the specific name is therefore queried.

Dimensions of specimen with valves in contact.—Height=50 mm.; length = 33 mm.; breadth = 33 mm.

Horizon.—Lower Oolite.

Loc.—About 3 miles north of Iraony.

PERNA LATOCONVEXA, sp. nov. (Pl. II. figs. 6, 7.)

Shell oblong, subquadrate, broadly convex, rugose; cardinal margin horizontal, incurved, and of medium length; umbo acute and curved anteriorly; anterior margin concave beneath the umbo (= byssal orifice) and afterwards nearly straight; posterior margin curved and depressed; hinge-area obscurely showing the ligamental pits and ridges; surface ornamented with a few coarse lines of growth.

Dimensions.—Height = 67 mm.; length = 48 mm.; depth = 15 mm.

This specimen consists of an external surface of a right valve, with a somewhat fractured posterior margin. It appears to have relations with *Perna quadrata*, Phillips,[2] and with *Perna rugosa*, Münster.[3] Both these species, however, are more or less angulated and flatter; they possess a deeper concavity beneath the umbones, and have rounder anterior margins.

Horizon.—Oolite (probably Lower), from the same rocks as those which contain *Steneosaurus Baroni*.

Loc.—Andranosamonta village.

GERVILLIA IRAONENSIS, sp. nov. (Pl. II. figs. 8, 9.)

Shell thick, ovately oblique, anteriorly twisted; both valves convex, the left one more so than the right; hinge-area thick,

[1] 'Syrian Molluscan Fossils,' Mem. Mus. Comp. Zool. Harvard, 1884, p. 59, pl. vi. fig. 1.

[2] 'Illustrations of the Geology of Yorkshire,' 1829, pl. ix. fig. 21.

[3] Goldfuss, 'Petrefact. Germaniæ,' 1836, vol. ii. p. 105, pl. cviii. fig. 2.

oblique, and extending nearly $\frac{2}{3}$ the height of the shell; umbones obtuse and terminating on the dorso-anterior margin of the hinge-line; anterior wing rudimentary, posterior oblique; surface worn, but showing concentric foldings at the margins of the valves.

Dimensions: specimen with valves in contact.—Height=45 mm.; length=30 mm.; diameter=25 mm.

The ligamental space between the hinges is wide and deep, but through bad preservation none of the pits are visible. This form differs from *G.* (*Gastrochæna*) *tortuosa*, J. de C. Sowerby,[1] in being much more convex, less tortuous, longer, and in possessing a deeper ligamental furrow. It is distinguished from *G. Hartmanni*, Münster,[2] by its rudimentary anterior auricle and shorter hinge.

Horizon.—Lower Oolite.

Loc.—About 3 miles north of Iraony.

Lima iraonensis, sp. nov. (Pl. III. fig. 2.)

Shell subtriangular, rather flattened, having its greatest convexity over the umbonal and posterior areas, and more or less compressed in the anterior and ventral directions; umbo acute and incurved; anterior auricle short and sloping; posterior area obliquely margined, and making a vertical descent to the elongate and concave byssal region; surface ornamented with numerous smooth and flattened ribs (about 54) radiating from the umbo; these ribs attain their maximum width near the ventral margin, where they measure 1 mm. across; they take a slightly undulating course, and are separated by well defined grooves minutely punctated; concentric lines of growth cross the ribs at irregular intervals; the byssal area is marked with coarse concave costæ; ventral margin imperfect.

Dimensions.—Height = 35 mm.; length = 37 mm.; depth = 10 mm. (max.).

This specimen is more acutely umboned than *Lima impressa* of Morris & Lycett, and its posterior margin is much sharper; both, however, have the punctations between the ribs. It approximates rather closely to *L. amnifera* of Whidborne,[3] from the Inferior Oolite, but the ribs in this form appear to stop short over the umbonal area, and the punctæ are not so numerous. It is named *Lima iraonensis* after its locality.

Horizon.—Lower Oolite.

Loc.—About 3 miles north of Iraony.

Pteroperna (allied to) costatula. (Pl. III. fig. 1.)

This is represented by the impression of a left valve of a very young specimen contained in the same sandstone as that in which specimens of *Trigonia pullus*, etc. occur. It is well ornamented with curved radiating ribs, and the extent of the hinge-line is moderately definite, but the groove on the posterior expansion is not clearly seen.

[1] 'Mineral Conchology,' vol. vi. (1826) p. 49, pl. dxxvi. fig. 1.
[2] Goldfuss, 'Petref. Germaniæ,' vol. ii. (1836) p. 122, pl. cxv. fig. 7.
[3] Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 504, pl. xvii. fig. 2.

Dimensions.—Height = 8 mm.; extent of hinge-line = 9 mm.

The adult form of this species has been previously recorded from Iraony.[1]

Horizon.—Oolite (probably Lower).

Loc.—Antankarana province, on the north-western boundary of the central hill-range.

Trigonia pullus, J. de C. Sowerby. (Pl. III. figs. 6, 7.)

This is a sandstone-impression accompanying *Pteroperna costatula*, *Astarte depressa*, etc. It is an extremely small form of the species, but is sufficiently marked for identification by the typically strong pallial costæ.

Fig. 7 appears to be a cast of the same species; it shows the bifid nature of the dental area.

This species has a wide distribution, having been recorded from the Antalo Limestones of Abyssinia[2]; from Shoa,[3] S. of Abyssinia; and from Cutch[4] in India.

Horizon.—Oolite (probably Lower).

Loc.—Antankarana province, on the north-western boundary of the central hill-range.

Trigonia costata, Parkinson. (Pl. III. fig. 5.)

The pallial costæ in this specimen appear to be slightly nodulated, but that is due to weathering; in other respects it corresponds with this species. It also shows the smooth sulcus separating the costæ from the marginal carina.

This species has been recorded from Abyssinia by W. T. Blanford, and from India by J. de C. Sowerby.

Horizon.—Lower Oolite.

Loc.—About 3 miles north of Iraony.

Astarte (allied to) depressa, Goldfuss (Münster). (Pl. III. fig. 8.)

An impression of a left valve in sandstone, accompanying *Pteroperna costatula* and *Trigonia pullus*; showing a strong concentric ornamentation, an oblique cardinal margin, and a small lunule. It is depressed, and has a length greater than its height.

Dimensions.—Length=10 mm.; height=7 mm.

Horizon.—Oolite (probably Lower).

Loc.—Antankarana province, on the north-western boundary of the central hill-range.

Mytilus madagascariensis, sp. nov. (Pl. III. fig. 3.)

Shell cuneiform, depressed posteriorly and elevated anteriorly, producing a narrow convexity, which becomes more pronounced

[1] R. B. Newton, Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 335.

[2] W. T. Blanford, 'Observ. Geol. Zool. Abyssinia,' 1870, p. 179.

[3] Douvillé, Bull. Soc. géol. France, ser. 3, vol. xiv. (1886) p. 226, pl. xii. figs. 13, 14.

[4] J. de C. Sowerby, Trans. Geol. Soc. ser. 2, vol. v. pt. ii. (1840) p. 328.

towards the umbonal area; anterior margin straight, with vertical sides; posterior area curved; ornamented with numerous, closely-set, concentric lines of growth.

Dimensions.—Height = 44 mm.; length = 25 mm.; depth = 10 mm.

This specimen consists of a fragmentary right valve of a *Mytilus*, with, unfortunately, its umbonal and hinge characters missing. The shell-structure is well preserved, exhibiting most distinctly the fine concentric striæ. This, together with its almost straight anterior margin and its generally depressed form, would suggest its being a new species. It probably comes closest to *Mytilus tigrensis* of W. T. Blanford[1] from the Antalo Limestones of Abyssinia, which has its valves of a similar depth, but is decidedly more broadly convex, having a curved anterior elevation and possessing less regular lines of growth.

Horizon.—From the Oolite (probably Lower), associated with *Steneosaurus Baroni*.

Loc.—Andranosamonta village.

Modiola angustissima, sp. nov. (Pl. III. fig. 4.)

Shell elongate-oval, strongly arched; anterior side deep, umbonal, and rather concave; posterior side obliquely curved; vertical area narrow and acutely terminal; ornamented with numerous concentric imbricating striæ.

Dimensions.—Height = 33 mm.; length = 15 mm.; depth = 11 mm.

This is represented by a right valve, with its shell-structure beautifully preserved though somewhat fractured posteriorly. It is a narrower and straighter form than Sowerby's *Modiola imbricata*, with a more vertical anterior side. It is regarded as a new species under the name of *Modiola angustissima*. The specimen was obtained from the matrix enclosing the remains of *Steneosaurus Baroni*.

Horizon.—Lower Oolite.

Loc.—Andranosamonta village.

Corbula pectinata, J. de C. Sowerby. (Pl. III. figs. 17, 18.)

Corbula lyrata, J. de C. Sowerby, Trans. Geol. Soc. London, ser. 2, vol. v. pt. ii. (1840) p. 327, pl. xxi. fig. 13.

Corbula pectinata, J. de C. Sowerby, *ibid.* vol. v. pt. iii. (1840) p. 718, pl. lxi. fig. 4.

The characters of this Indian species are very marked and definite. The shell is trigonal, subglobose, and of almost equal height and length; it has bold concentric and elevated ribs, between which are closely-set transverse striæ; these striæ are more pronounced on the left valve and nearly obsolete on the other; the anterior end is deeply excavated, but without any circumscribed lunule, while the posterior area exhibits a concave ligamental

[1] 'Observations on the Geology and Zoology of Abyssinia,' 1870, p. 201 & pl viii. fig. 3. (Type in British Museum.)

cavity having its sides carinated and its terminations slightly produced. *C. lyrata* and *C. pectinata* were originally regarded as separate species, but a comparison of the types in the Geological Society's Museum has compelled me to unite the two names, being convinced that they are the same. This being the case, I think it best to adopt *C. pectinata*, as it is much better figured and described than the other, both having been published in the same year. This shell appears to occur quite as abundantly in Madagascar as it does in India (Cutch), and is found associated with *Corbula Grandidieri* and *Astarte Baroni*.

Dimensions.—Length = 23 mm.; height = 21 mm.; breadth = 17 mm.

Horizon.—Oolite (probably Lower).

Loc.—About 2 miles south of Andranosamonta village.

Corbula Grandidieri, sp. nov. (Pl. III. figs. 15, 16.)

Shell subglobose, nearly equivalve, inequilateral, subtrigonal, and concentrically furrowed; posterior area carinated, oblique, and vertically ribbed, containing a narrow and elongate ligamental depression; umbones incurved, contiguous and anterior; the space beneath the umbones is deeply excavated, though without a definite lunule; ventral border curved. Dentition not known.

Dimensions of the largest example.—Length = 32 mm.; height = 27 mm.; breadth = 21 mm.

This shell is regarded as a new species under the name of *Corbula Grandidieri*, in honour of the celebrated French naturalist, M. Alfred Grandidier, who has done so much towards the scientific development of Madagascar. It mainly differs from *Corbula pectinata*, with which it was found associated together with *Astarte Baroni*, in the absence of sculpture between the concentric furrows, and in having a more prominent and more ornamented posterior area.

Horizon.—Oolite (probably Lower).

Loc.—About 2 miles south of Andranosamonta village.

Pseudotrapezium ventricosum, sp. nov. (Pl. III. figs. 9, 10.)

Shell ovately elongate, equivalve, slightly inequilateral, ventricose; anterior margin short, posterior long; ornamented with numerous concentric growth-lines rather irregularly set; ligament external; the umbones are antero-mesial, contiguous and strongly incurved; lunule absent; posterior area obliquely carinated, and enclosing a prominent lanceolate escutcheon depressed beneath the umbones, but becoming afterwards sharply convex.

Dimensions (valves in contact).—Height = 26 mm.; length = 42 mm.; breadth = 23 mm. The escutcheon measures 25 × 15 mm.

On account of the strongly carinated posterior margins and its extensive escutcheon-area, this specimen is placed in Fischer's genus, *Pseudotrapezium*, the type of which is *Cypricardia bathonica*,

d'Orbigny. This differs from the Malagasy shell in being much more trigonal in shape, in its possession of a more angulated space beneath the umbones on the escutcheon, and in having slightly recurved umbones.

Horizon.—Oolite (probably Lower).

Loc.—About 2 miles south of Andranosamonta village.

Pseudotrapezium depressum, sp. nov. (Pl. III. figs. 11, 12.)

Shell with valves in contact, and differing from the last species in being much more depressed, in having a greater height and length, and in possessing a narrower and dorsally angulated escutcheon area; it has a similar concentric ornamentation.

Dimensions.—Height = 31 mm.; length = 45 mm.; breadth = 17 mm.; escutcheon = 29 × 12 mm.

Horizon.—Oolite (probably Lower).

Loc.—About 2 miles south of Andranosamonta village.

Pseudotrapezium elongatum, sp. nov. (Pl. III. figs. 13, 14.)

This specimen appears to be distinct from the other two species in its smaller dimensions. It has the narrow and dorsally angulated escutcheon area, but possesses a sharper and rather more trigonal contour.

Dimensions.—Height = 20 mm.; length = 35 mm.; breadth = 15 mm.

Horizon.—Oolite (probably Lower).

Loc.—About 2 miles south of Andranosamonta village.

Brachiopoda.

Rhynchonella (allied to) plicatella, J. de C. Sowerby.

This species has been already recorded from near Ankoala.[1]

Horizon.—Jurassic.

Loc.—Hill-range between the River Lokia or Loquez and the River Rodo, north-east coast.

Rhynchonella (allied to) concinna, J. Sowerby.

[British, European, and Indian.]

Horizon.—Lower Oolite.

Loc.—About 3 miles north of Iraony.

Plantæ.

There are some obscure plant-remains in a lignite of uncertain age obtained from Ambavatoby on the west coast. This lignite is probably Cretaceous or Jurassic, and has been noticed 'as older than Tertiary' (Annales des Mines, ser. 5, vol. vi. 1854, pp. 570–576);

[1] R. B. Newton, Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 337.

it has also been doubtfully referred to a Permo-Carboniferous horizon by Cortese (*op. cit.* Boll. R. Com. geol. Ital.). One of the specimens collected by Mr. Baron shows the cell-structure of *Equisetum* (*fide* W. Carruthers, F.R.S.), and another appears to be an impression of a fern.

IV. Note on the Structures of some Limestones from Madagascar.

A number of limestones collected by Mr. Baron from various localities, extending from Jangina, in South-west Central Madagascar, to the northern parts of the island, have been carefully sliced and microscopically examined. They mostly present ordinary oolite structures, the granules exhibiting the usual concentric and radiate characters. Many of these limestones contain organisms such as foraminifera (*Cristellaria*, *Textularia*, *Marginulina*, etc.), mollusca (*Nerinœa*), polyzoa, corals, etc., but the most interesting form determined is that of *Girvanella*, which appears to enter largely into the composition of these rocks. The minute tubules of this genus, which occur in spherules of a variety of sizes, are best seen in a black crystalline rock obtained from W. of Ankaramy, off the north-western coast. The *Girvanella*-spherule in this specimen is extremely large, and measures 10 mm. in diameter. Another limestone from the Antankarana province exhibits a similar structure, and according to Mr. Wethered resembles his species *G. pisolitica*,[1] from British Jurassic strata. This genus, although regarded at the time of description by Messrs. Nicholson and Etheridge, Jun., as possessing rhizopodal affinities, is now generally considered to belong to the calcareous algæ. It has a wide distribution both geographically and geologically, having been discovered in limestones ranging from Cambrian to Jurassic times, and is recorded from Britain, Europe, America, and Australia. None of the organisms mentioned, however, assist one to fix the precise age of the rocks in which they are found, although I am in favour of assigning them to the Jurassic period, and this chiefly on account of the presence of a brachiopod allied to *Rhynchonella plicatella* in one of the limestones collected from the neighbourhood of the River Lokia or Loquez, and from which many of these rock-specimens were procured.

Lastly, a microscopic examination has been made of the Cretaceous limestone forming the Ambohimarina hill, in which the specimen of *Lampadaster* was discovered. This having been proved to be largely composed of *Globigerinæ*, it is suggested that it be termed a *Globigerina*-limestone.

[1] Geol. Mag. 1889, p. 196, pl. vi. figs. 10, 11.

V. List of all the recognized Fossils from Madagascar.

QUATERNARY.

Mammalia.

Megaladapis madagascariensis, Forsyth Major.[1]
Hippopotamus Lemerlei, Grandidier & Milne-Edwards.[2]
„ *leptorhynchus*, Grandidier & Filhol.[3]
Sus, sp.[1]
Bos, sp.[1]
Potamochœrus, sp.[1]

Aves.

Æpyornis cursor, M.-Edw. & Grandidier.[4]
„ *Hildebrandti*, Burckhardt.[5]
„ *ingens*, M.-Edw. & Grandidier.[4]
„ *lentus*, M.-Edw. & Grandidier.[4]
„ *maximus*, Geoff. St.-Hilaire.[6]
„ *medius*, M.-Edw. & Grandidier.[4]
„ *modestus*, M.-Edw. & Grandidier.[4]
„ *Mulleri*, M.-Edw. & Grandidier.[4]
„ *titan*, C. W. Andrews.[7]
Mullerornis agilis, „ *Betsilei*, „ *rudis*, } M.-Edw. & Grandidier.[4]

Reptilia.

Crocodilus robustus, Grandidier & Vaillant.[8]
Testudo Grandidieri, Vaillant.[9]
„ *abrupta*, Grandidier.[2]

Mollusca.

Gasteropoda.

Achatina panthera, Férussac.
„ „ sp.

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[1] 'On *Megaladapis madagascariensis*, an extinct gigantic Lemuroid from Madagascar; with remarks on the associated Fauna, and on its geological age,' Phil. Trans. Roy. Soc. vol. clxxxv. (1894) pp. 15–38, pls. v.–vii.

[2] 'Sur des découvertes zoologiques faites récemment à Madagascar par M. Alfred Grandidier,' Comptes-rendus Acad. Sci. Paris, vol. lxvii. (1868) p. 1165.

[3] 'Observations relatives aux ossements d'Hippopotames trouvés dans le marais d'Ambolisatra à Madagascar,' Ann. Sci. Nat. Zool. ser. 7, vol. xvi. (1894) p. 184.

[4] 'Observations sur les *Æpyornis* de Madagascar,' Comptes-rendus Acad. Sci. Paris, vol. cxviii. (1894) pp. 122-127.

[5] 'Ueber *Æpyornis*,' Palæontologische Abhandlungen (Dames & Kayser), vol. vi. (1893) pp. 127–145, pls. xiii.–xvi.

[6] 'Notice sur des ossements et des œufs trouvés à Madagascar, dans des alluvions modernes, et provenant d'un oiseau gigantesque,' Ann. Sci. Nat. ser. 3, vol. xiv. (1850) p. 206.

[7] 'On some remains of *Æpyornis* in the British Museum (Nat. Hist.),' Proc. Zool. Soc. 1894, pp. 108–123, pls. xiv. & xv.

[8] 'Sur le Crocodile fossile d'Amboulintsatre (Madagascar),' Comptes-rendus Acad. Sci. Paris, vol. lxxv. (1872) p. 150.

[9] 'Remarques complémentaires sur les Tortues gigantesques de Madagascar, Comptes-rendus Acad. Sci. Paris, vol. c. (1885) pp. 874–877.

Buliminus (*Rachis*) *punctatus*, Anton.
Pomatias (*Tropidophora*) *virgata*, G. B. Sowerby.
„ (*Otopoma*?) *Grandidieri*, Crosse & Fischer.[2]
Planorbis trivialis, Morelet.[1]
Limnæa Hovarum, Tristram.[1]
Bulimus Favannei, Lamarck.
„ *Grandidieri*, Crosse & Fischer.
„ *subobtusatus*, Crosse & Fischer.
„ (allied to) *crassilabris*, Gray.
Helix, sp.
Pleurotoma tigrina, Lamarck.[2]
Vertagus recurvus, G. B. Sowerby.[2]

Lamellibranchiata.

Paphia glabrata, Gmelin.[3]
Lucina tigrina, Linnæus.

TERTIARY.

Eocene.

Mollusca.

Gasteropoda.

Neritina Schmideliana, Chemnitz.
Terebellum (like) *obtusum*, J. de C. Sowerby.

Lamellibranchiata.

Ostrea pelecydion, Fischer.
„ *Grandidieri*, Fischer.
„ *hippocastanum*, Fischer.

Foraminifera.

Alveolina oblonga, d'Orbigny.
„ *longa*, Czjzek.
„ (allied to) *ovoidea*, d'Orbigny.
Nummulites Beaumonti, d'Archiac & Haime.
„ *subbeaumonti*, de la Harpe.
„ *acutus*, J. de C. Sowerby.
„ *obesus*, d'Archiac & Haime.
„ *biarritzensis*, d'Archiac & Haime.
„ *Ramondi*, Defrance.
„ (allied to) *Bellardii*, d'Archiac.
„ *perforatus*, d'Orbigny.
„ *complanatus*, Lamarck.
Assilina spira, Roissy.
Orbitoides (allied to) *papyracea*, Boubée.
Orbitolites (?).
Rotalia (?).
Triloculina (like) *trigonula*, d'Orbigny.

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[1] These species were collected by the Rev. Jas. Wills, at Sirabé, in Northern Betsileo.
[2] Obtained by Mr. Last, from Ambatomifoko, south-west coast.
[3] Collected by Mr. Baron, at Fiherenana, south-west coast.

SECONDARY.

Cretaceous.

Mollusca.

Cephalopoda.

Nautilus Fittoni, Sharpe. (Upper Cretaceous.)
Belemnites conicus, Blainville. } Neocomian.
„ *polygonalis*, Blainville. }
„ *pistilliformis*, Blainville. }
„ *binervius*, Raspail. }

Lamellibranchiata.

Alectryonia ungulata, Schlotheim. }
„ *pectinata*, Lamarck. }
„ *Deshayesi* (?), Fischer de Waldheim. } Upper Cretaceous.
Gryphæa vesicularis, Lamarck. }
Exogyra ratisbonensis, Schlotheim. Middle Cretaceous.
Lima, sp. } Neocomian.
Pecten, sp. }

Echinodermata.

Lampadaster Grandidieri, G. Cotteau. } Upper Cretaceous.
Guettaria Rocardi, G. Cotteau. }

Foraminifera.

Globigerina, sp. }
Frondicularia, sp. } Upper Cretaceous.
Nodosaria, sp. }
Bulimina? }

Jurassic.

Reptilia.

Steneosaurus Baroni, R. B. Newton. Lower Oolite.

Mollusca.

Cephalopoda.

Belemnites Sauvanausus, d'Orbigny. }
„ *hastatus*, Blainville. }
Perisphinctes (allied to) *polygyratus*, Reinecke. } Oxfordian
Rhyncholites (allied to) *gigantea*, d'Orbigny. }
Stephanoceras macrocephalum, Schlotheim. }
„ *Parkinsoni*, J. Sowerby. Inferior Oolite.
„ *Herveyi*, J. Sowerby. Lower Oolite.
„ *calloviense*, J. Sowerby. Callovien.
Lytoceras fimbriatum, d'Orbigny. } Lias.
Phylloceras heterophyllum, J. Sowerby. }

Gasteropoda.

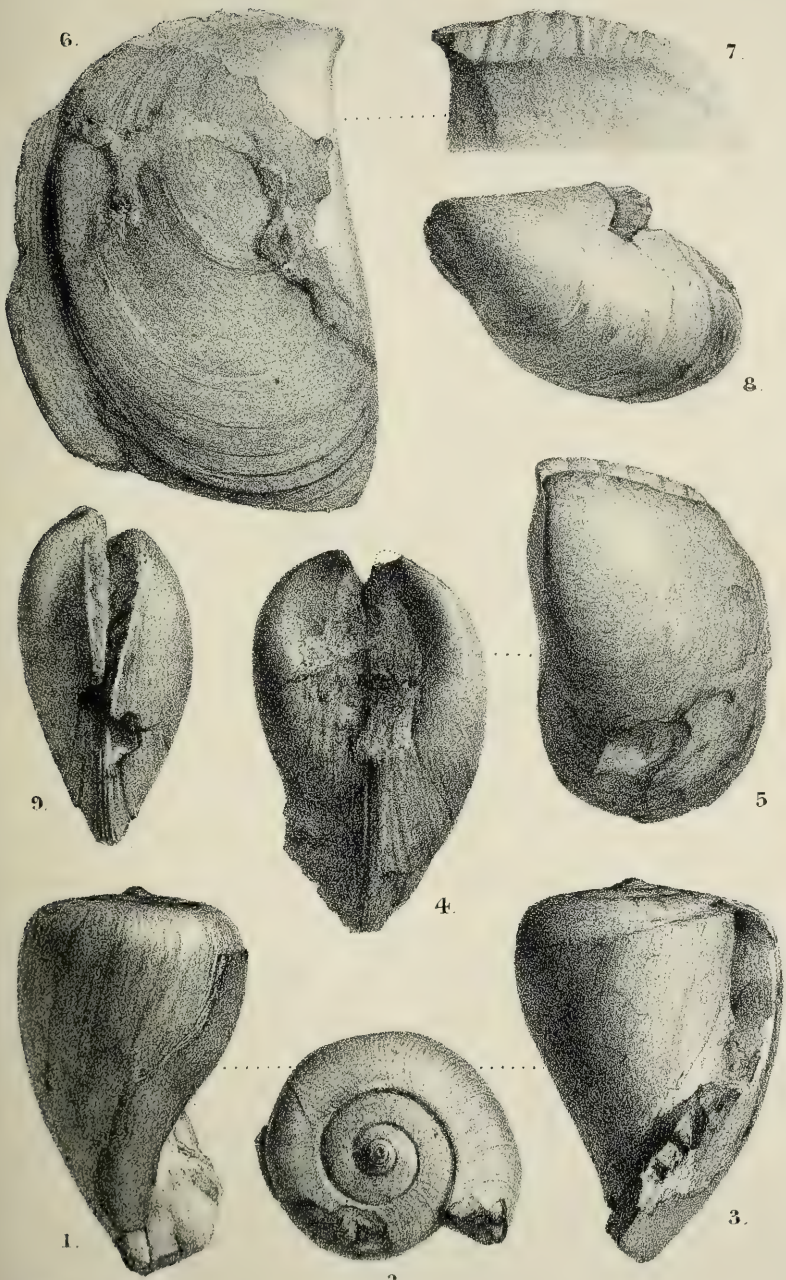
Nerita Buvignieri, Morris & Lycett.
Nerinæa (allied to) *Eudesi*, Morris & Lycett.
„ „ *Voltzi*, Deslongchamps.
Natica „ *intermedia*, Morris & Lycett. } Lower Oolite.
„ „ *Verneuili*, d'Archiac.
„ „ *cincta*, Phillips.
„ „ *canaliculata*, Morris & Lycett.
„ „ *Clio*, d'Orbigny. Oxfordian.
„ *dubia*, Römer. Kimeridge.
Nerinæa leiogyra, Fischer. Jurassic.
Cerithium eribote, d'Orbigny. } Oxfordian.
„ (like) *russiense*, d'Orbigny.
Solarium (near to) *polygonum*, d'Archiac. } Great Oolite.
Trochus „ *Ibbetsoni*, Morris.
Alaria, sp.
Eulima, sp.
Trochactæonina Richardsoni, R. B. Newton (sp. nov.). Lower Oolite.

Lamellibranchiata.

Ostrea Sowerbyi, Morris & Lycett.
Alectryonia gregaria, J. Sowerby.
Perna mytiloides, Lamarck.
„ *orientalis* (?), Hamlin.
„ *latoconvexa*, R. B. Newton (sp. nov.).
Pteroperna costatula, Deslongchamps.
Gervillia iraonensis, R. B. Newton (sp. nov.).
Lima iraonensis, R. B. Newton (sp. nov.).
Modiola imbricata, J. Sowerby.
„ *angustissima*, R. B. Newton (sp. nov.).
Mytilus madagascariensis, R. B. Newton (sp. nov.). } Lower Oolite.
Cardium Grandidieri, R. B. Newton (sp. nov.).
Cypricardia rostrata, J. Sowerby.
„ (allied to) *bathonica*, d'Orbigny.
Pseudotrapezium ventricosum, R. B. Newton (sp. nov.).
„ *depressum*, R. B. Newton (sp. nov.).
„ *elongatum*, R. B. Newton (sp. nov.).
Trigonia pullus, J. de C. Sowerby.
„ *costata*, Parkinson.
Astarte (allied to) *angulata*, Morris & Lycett.
„ „ *depressa*, Münster (Goldfuss).
„ „ *alta*, Goldfuss. Lias.
„ „ *Phyllis*, d'Orbigny. Oxfordian.
„ „ *minima*, Phillips.
„ (?) *Baroni*, R. B. Newton.
„ (allied to) *excavata*, J. Sowerby.
Sphæra madagascariensis, R. B. Newton.
Corbula pectinata, J. de C. Sowerby. } Lower Oolite.
Pholadomya ambigua, J. Sowerby.
Ceromya concentrica, J. de C. Sowerby.
Opis (allied to) *trigonalis*, J. de C. Sowerby.
Lucina Bellona, d'Orbigny.
Myopsis dilata, Phillips.
Nucula ovata, Zieten. Lias.

Brachiopoda.

Terebratula maxillata, J. de C. Sowerby. Lower Oolite.
Waldheimia perforata, Piette. Lias.



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JURASSIC MOLLUSCA FROM MADAGASCAR.

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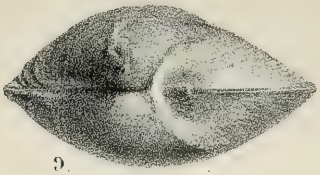
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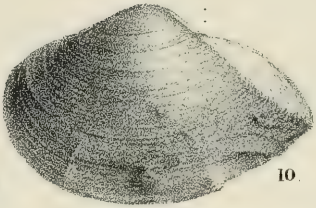
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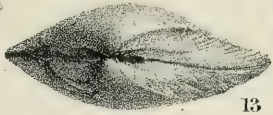
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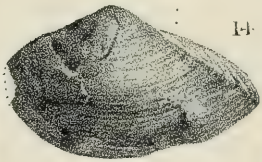
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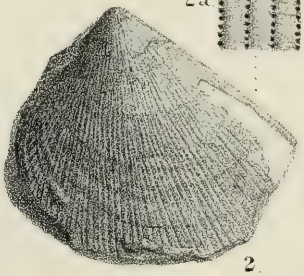
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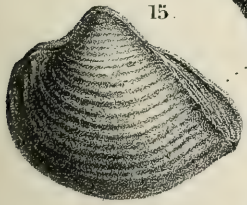
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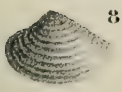
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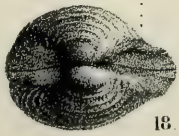
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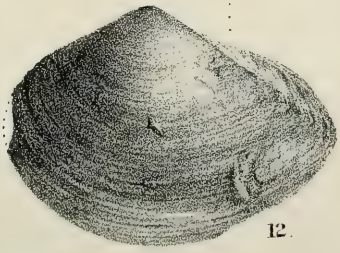
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JURASSIC MOLLUSCA FROM MADAGASCAR.

Rhynchonella (allied to) *variabilis*, Schlotheim.
„ „ *plicatella*, J. de C. Sowerby. } Lower Oolite.
„ *concinna*, J. Sowerby.
„ *obsoleta*, J. Sowerby.
„ (allied to) *tetrahedra*, J. Sowerby. Lias & Lower Oolite.

Echinodermata.

Pentacrinus, sp. Lias (?).
Acrosalenia, sp. Lias.
Stomechinus (allied to) *bigranularis*, Lamarck. Lower Oolite.

Actinozoa.

Montlivaltia trochoides, M.-Edw. & Haime. Lower Oolite.
Epismilia Grandidieri, Fromentel.
Isastræa Fischeri, Fromentel. } Lias (?).
Thamnastræa.

Foraminifera.

Textularia, sp.
Cristellaria, sp.
Lituola?
Marginulina, sp. } Jurassic (?).
Nummulites, sp.
Planorbulina, sp.

Plantæ.

Girvanella, sp. Calcareous Algæ (?). } Jurassic (?).
Equisetum, sp. Equisetaceæ.

EXPLANATION OF PLATES II. & III.

Jurassic fossils from N.W. Madagascar.

Plate II.

Figs. 1, 2, 3. *Trochactæonina Richardsoni*, sp. nov.
„ 4, 5. *Perna orientalis* (?).
„ 6, 7. *Perna latoconvexa*, sp. nov.
„ 8, 9. *Gervillia iraonensis*, sp. nov.

Plate III.

Fig. 1. *Pteroperna costatula*, young form.
„ 2, 2 *a*. *Lima iraonensis*, sp. nov.
„ 3. *Mytilus madagascariensis*, sp. nov.
„ 4. *Modiola angustissima*, sp. nov.
„ 5. *Trigonia costata*.
Figs. 6, 7. *Trigonia pullus*.
Fig. 8. *Astarte* (allied to) *depressa*.
Figs. 9, 10. *Pseudotrapezium ventricosum*, sp. nov.
„ 11, 12. *Pseudotrapezium depressum*, sp. nov.
„ 13, 14. *Pseudotrapezium elongatum*, sp. nov.
„ 15, 16. *Corbula Grandidieri*, sp. nov.
„ 17, 18. *Corbula pectinata*.

All the figures are drawn natural size, with the exception of 1, 6, and 8 of Plate III., which are enlarged 1½ times; fig. 2 *a* of the same Plate is a magnified portion of fig. 2, showing the punctæ between the ribs.

Discussion (on the two preceding Papers).

The President pointed out that while many of the missionaries in Madagascar had paid attention to the Quaternary deposits of that island, and had sent home numerous remains of many species of gigantic wingless birds (like the *Dinornis* in New Zealand), Mr. Baron had, in his former and present communications to the Society, made us acquainted with a series of formations and fossils extending from the Jurassic to the Tertiaries; and, thanks to Mr. R. B. Newton, the fossils from these several deposits had all been identified and named. Mr. Baron had further shown that there were volcanic rocks and evidences of old volcanic action. He had shown that some of the old lake-basins were also connected with hot springs and volcanic vents. In these dried-up or partly dried-up lakes vast deposits of bones had been observed by Mr. Baron and by other missionaries—principally bones of *Æpyornis*, *Hippopotamus*, *Palæolemur*, *Testudo*, and Crocodilian bones. Mr. Baron was fortunate in having Mr. Newton to examine and name the fossils which he had so successfully collected.

Dr. Du Riche Preller pointed out that close to the rock termed 'foyaite' by Mr. Baron appeared nepheline-phonolite, which latter is simply a younger form of foyaite, and that the association of both bears close analogy to the foyaite or elæolitic syenite of Southern Portugal. The latter outcrop occurs in Jurassic strata, and hence the inference is justifiable that the area in which foyaite and phonolite occur in the North-west of Madagascar, and which the Author marks 'unknown,' is also Jurassic.

Dr. J. W. Gregory remarked on the close and interesting analogy between this area, the Peninsular region of India, and the mainland of Africa. The gneiss seemed to resemble that which forms the whole tableland of East Africa, and is covered by volcanic rocks of the same types. Probably in Madagascar occurs the same sequence from trachytes to andesites and basalts as can be demonstrated on the mainland. The occurrence of ancient lake-basins of vast area is another resemblance to East Africa. The association of the volcanic rocks with marine sediments is of value, as it may help to determine the age of the volcanic series of British East Africa. The map seems to confirm that issued by Cortese about six years ago.

Mr. W. W. Watts stated that a large number of Mr. Baron's slides had passed through his hands, and he could testify to the thoroughness of the Author's work and the care which he had devoted to his determinations. He called attention to the resemblance between the rocks of the gneissose area and those of the North-west Highlands. In reply to Dr. Preller, he said that he had not seen Mr. Baron's foyaite, but he had seen the phonolites and haüyne-rocks. Knowing what we do of the eruption of rocks of similar composition in widely different ages, he thought it would hardly be wise to map an area of rocks as Mesozoic, merely because they happened to be penetrated by a boss of foyaite.

Mr. W. H. Hudleston also spoke, and Mr. R. B. Newton replied for his paper.

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[The Editor of the Quarterly Journal is directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

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PART 2.

THE

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TO BE HELD AT BURLINGTON HOUSE.

SESSION 1894–95.

1895.

Wednesday, May 8–22
„ June 5–19

[*Business will commence at Eight o'Clock precisely each Evening.*]

9. *On the* PHYSICAL CONDITIONS *of the* MEDITERRANEAN BASIN *which have* RESULTED *in a* COMMUNITY *of some* SPECIES *of* FRESHWATER FISHES *in the* NILE *and the* JORDAN WATERS. By Prof. E. HULL, M.A., LL.D., F.R.S., F.G.S. (Read February 6th, 1895.)

[Abstract.]

The Author summarizes the evidence in favour of the existence of barriers in post-Miocene times, separating the Mediterranean area into a chain of basins. He brings forward arguments in support of his contention that the waters of the eastern (Levantine) basin became fresh during a period when the area of evaporation was smaller, and the supply of river-water greater, than at present. Into this freshwater lake the waters of the Nile would flow directly. He has elsewhere given reasons for believing that the Jordan Valley from Lake Huleh to Arabah was the bed of a lake over 200 miles long, and at least 1300 feet above the present level of the Dead Sea. He suggests that the waters of this lake escaped into the Levantine basin through the plain of Esdraelon. With such physical conditions existing, the fauna of the Levantine basin would have a means of spreading throughout the whole system of waterways connected with it.

In conclusion the Author adds some observations on the changes which occurred in the Mediterranean area subsequent to the post-Miocene epoch of earth-movement.

DISCUSSION.

Dr. BLANFORD thought that the distribution of marine Upper Tertiary beds in the Eastern Mediterranean area was not in accordance with the Author's theory. He especially drew attention to the well-known marine Pliocene beds of Italy, Sicily, and Greece. Moreover, if the hypothetical freshwater lake in the Levant accounted for the presence of Chromididæ in the Jordan, in Asia Minor, and in Tripoli, how was their absence in all European rivers that run into the Mediterranean, the Black Sea, and the Caspian to be explained?

Dr. GREGORY said that the paper raised several interesting questions and carried us back to some ancient authorities. The Author's theory assumed, and was proposed to explain, the introduction of the Jordan fish-fauna from the Mediterranean. But there was only one species (a blenny) common to the two, and the faunas were as different as they could well be. He quoted Dr. Günther to show that the difficulty in regard to the origin of the Jordan fish-fauna is that it contains a group of forms which are absent from N.E. Africa. This, the real difficulty, was apparently not appreciated by Prof. Hull. The speaker showed that the evidence of other groups was of the same character. He thought

no reliance could be placed on the Author's table of statistics, as the paper showed that these rested (at least in part) on the work of authorities long since out of date. The Author said that it was unquestioned that in Pliocene times the Mediterranean and Red Seas had been united; the speaker thought it was now unquestioned that no such connexion could have occurred in Kainozoic times. He was surprised to hear the myth of the Sahara cockles again seriously quoted.

Dr. Du Riche Preller wished to ask the Author on whose authority and on what submarine surveys his map of the supposed Mediterranean lake-basins rested.

The Author, replying to Dr. Blanford, said that he was unable to see why the absence of fishes of the genera *Chromis* and *Hemichromis* from the rivers entering the Caspian or Black Sea could be considered an objection to the views which he had advanced. Even supposing that they had frequented these streams at the period referred to, they may have since disappeared, owing to physical changes. The point of importance was that they now inhabit both the African and Jordanic streams and lakes.

The Author was quite aware of the difference of the fauna of the Red Sea and Mediterranean, notwithstanding that during the period of submergence in Pluvial times (220 feet in Lower Egypt) the waters of the two seas had been united across the Isthmus of Suez, and he had treated the subject very fully in the Geological Memoir on Sinai and Palestine (p. 76). On the emergence of the land and the conversion of the Isthmus into land, differentiation naturally took place: the Mediterranean fauna gradually becoming assimilated to that of the Atlantic, and the Red Sea fauna to that of the Indian Ocean.

Replying to Dr. Gregory, the Author said he could not admit that there had ever been any communication between the Jordanic waters and those of the Red Sea along the Gulf of Akabah since the emergence in post-Eocene times. All the evidence was against such a view, as the highest lake-terraces in the Arabah Valley were cut off by the saddle rising to the south of them to a height of about 600 feet. The ridge bounding the valley on the east from the Jordan to the Gulf of Akabah, which on a map resembled the banks of a continuous river-valley, really indicated the line of the great fault along which the rocks were elevated on that side. It was not a true river-valley—only a continuous broken escarpment.

Replying to Dr. Preller, the Author stated that the 250-fathom contour on the map was taken partly from soundings by Admiral Spratt and partly from the Admiralty Charts.

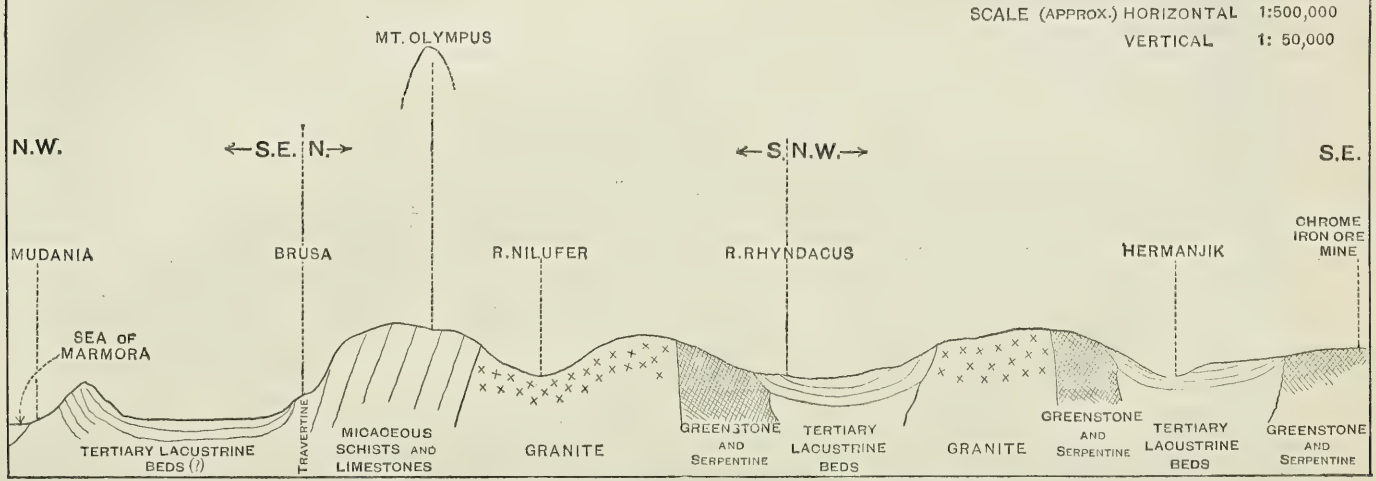
10. Notes *on the* Geology *and* Mineral Resources *of* Anatolia (Asia Minor). By W. F. Wilkinson, Esq., F.G.S. (Read January 9th, 1895.)

So little is known of the geography and geology of the interior of Asia Minor that the following notes, made during a journey of about 50 miles inland from Brusa, may be worth recording. The route followed by the author passed through the following places, commencing at the coast:—Mudania, Brusa, Edrenos, and Hermanjik. Straight lines connecting Mudania with Edrenos, and Edrenos with Kutahia, would run roughly along the line of section accompanying this paper (see fig. 1, p. 96). Starting from the coast in a southerly direction, one crosses first of all a low range of mountains consisting principally of limestones, running parallel with the coast. About 15 miles east of Mudania are the marble quarries of Gemlek. After passing this range, which attains here an altitude of 1000 feet, the route crosses the plain of Brusa, watered by the Nilufer river, and covered with alluvial deposits. On the south side of the plain, and at the foot of the lofty range of Mount Olympus, lies the city of Brusa, the ancient capital of the Osmanlis, and still a city of considerable importance. The southern slopes of Mount Olympus consist of limestones and mica-schists. The granite, which is the backbone of the ridge, is not met with, in travelling due south of Brusa, till after a three hours' climb. This granite is principally a white variety, with dark mica. The higher peaks of Mount Olympus lie to the east; the loftiest of them is said to attain an altitude of 8350 feet. In the higher parts of Mount Olympus are several large lakes.

After crossing the Mount Olympus range, a descent is made to the valley of the Nilufer (anc. Odryses). The range of mountains which separates this valley from that of the Rhyndacus, one of the most important rivers of this part of Asia Minor, consists principally of eruptive rocks (granite) and metamorphic rocks (serpentine). Serpentine crops out one hour's ride south of the Nilufer river and continues to the Rhyndacus valley, where sedimentary strata (limestones and shales) again crop out. The ruins of Edrenos (anc. Adranos) castle are situated on a hill of limestone. The plain of Edrenos, which is next crossed, consists of shale and limestone-deposits. About 7 miles south-east of Edrenos, granite again comes to the surface, and farther south serpentine is met with. Before reaching Hermanjik a red ferruginous rock occurs in large quantities. At Hermanjik itself conglomerate-beds, marls, and limestone are found.

Farther south serpentine covers a large area, in which several chrome iron-ore deposits have been discovered and worked. Owing, however, to difficulties of transport, the industry has not attained the importance that it deserves. The chrome ore appears to occur

Fig.1. DIAGRAMMATIC SECTION Through MUDANIA, BRUSA, EDRENOS, and HERMANJIK.



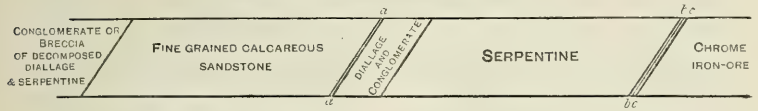
[*Note.*—Edrenos lies between the Rhyndacus Valley and the granite-ridge S.E. of it.]

The scale of 1 : 500,000 = ·1267 in^{ch}, or rather more than $\frac{1}{8}$ inch, to a mile.

in irregular masses in the serpentine, and is quarried out and sent down to the coast on camels, with no further treatment at the mines than a rough picking by hand.

In a cutting, made for draining the water from a quarry visited by the author, the accompanying section was seen :—

Fig. 2. (Scale = 1 : 300.)



a, *b*, *c* = Thin bands of dark-blue, white, and yellow clay respectively.

Besides the chromite-deposits above mentioned, the district is also remarkable for the occurrence of two other not very common minerals, namely meerschaum and boracite ; the former is mined on a large scale near the town of Eski Chehir, and the latter near Bali Kessir.

With regard to the distances, which have been stated in time, it may be mentioned that this is the usual way of reckoning distances in Anatolia. Naturally the number of miles travelled per hour varies with the condition of the 'road' and the more or less mountainous character of the country. In this journey, which was chiefly among mountains, the average distance covered per hour was probably only 3 miles.

The author would recommend the student of the geology of Western Asia Minor to consult the paper on this subject by Messrs. Hamilton and Strickland, Trans. Geol. Soc. ser. 2, vol. vi. pt. i. (1841) p. 1. In it will be found much valuable information regarding the age of the rock-formations. The origin of the Tertiary lacustrine deposits, over three of which the author passed, as shown in fig. 1, is there discussed at length.

Discussion.

Dr. Du Riche Preller observed that the juxtaposition of the serpentine and what the Author described as 'white' granite was very similar to the occurrence in the Island of Elba, where the celebrated white-mica granite was very valuable for the manufacture of glass. He therefore wished to ask the Author whether the granite in Anatolia was also quarried. The younger Elban granites and serpentines were intrusive in Eocene limestone and sandstone, and were therefore Tertiary, and, if the Author's section was correct, this appeared to be also the case in the Anatolian rocks.

The Author, in reply, said that he was not aware of the granite being worked commercially. As a rule, the mineral resources of Asia Minor were very much neglected.

11. *On the* EASTERN LIMITS *of the* YORKSHIRE *and* DERBYSHIRE *or* MIDLAND COALFIELD. By W. S. GRESLEY, Esq., F.G.S. (Read December 19th, 1894.)

[Abstract.]

The Author attempts to throw light on the question of the easterly extension of the Yorkshire, Derbyshire, and Nottinghamshire coalfield beneath the newer rocks. He notices the general trend of the strata, the sizes of other British coalfields, the question of the origin of mountains, stratigraphical considerations, and the faults of the North of England. His object is rather to suggest what he believes to be novel ways of treating the subject than of reaching conclusions or locating limits.

The Author calls attention to the previously established fact that an anticlinal exists in the Secondary rocks near the southern end of the Lincolnshire Wolds. The existence of this anticlinal has been demonstrated by Mr. A. J. Jukes-Browne (Quart. Journ. Geol. Soc. vol. xlix. 1893, p. 467). Following the reasoning of M. Marcel Bertrand, he infers that an anticlinal in the Carboniferous rocks probably underlies this, and that the easterly termination of productive Coal Measures under Lincolnshire may be formed by this anticlinal.

DISCUSSION.

Prof. HULL stated that at one time he had considered it probable that the Yorkshire and Derbyshire Coalfield was only the western section of a basin, the eastern section of which was concealed under Mesozoic beds. This was the view which he had advocated in a paper read some years ago before the Institution of Civil Engineers. But the results of the deep boring made at Scarle, near Lincoln, had somewhat altered his views on this point, as the cores of earthy limestone and breccia and chocolate-coloured clays, brought up from a depth of about 2000 feet, appeared to be referable to the Upper Coal Measures, so fully represented at Ardwick near Manchester, rather than to the Lower Carboniferous series. It was very desirable, however, that the matter should be further investigated by means of fresh borings.

Mr. MARR wished to direct the Author's attention to a paper by Prof. Arnold Lupton on the Geology of the West Yorkshire Coalfield (Trans. Fed. Inst. Mining Engineers, vol. vii. pt. i. 1894, p. 137).

12. *On some* PHASES *of the* STRUCTURE *and* PECULIARITIES *of the* IRON ORES *of the* LAKE SUPERIOR REGION. By W. S. GRESLEY, Esq., F.G.S. (Read December 19th, 1894.)

[Abstract.]

The Author has been studying heaps of ore brought from the region lying south-west of Lake Superior since 1890. He describes certain structural features of the ore-fragments, and discusses the evidences of mechanical movements and chemical alteration exhibited by these fragments.

13. *On the* Mean Radial Variation *of the* Globe.

By J. Logan Lobley, Esq., F.G.S. (Read January 23rd, 1895.)

[Abstract.]

The Author submits considerations (chiefly derived from the characters of the earlier sediments) which lead him to suppose that crust-folds have not been produced by continuous contraction of the Earth, and that the planetary heat and mean radius of the Earth have been practically invariable during the period which has elapsed since Cambrian times.

Discussion.

Prof. Hughes pointed out that the criticisms and speculations of the Author involved the assumption that the rocks of a contorted series once occupied the area that would now be covered by them if laid out evenly. But he thought that the examination of folded rocks in small specimens or in mountain-masses showed clearly that the larger surface was produced at the expense of their thickness, and that in many cases they never extended over a larger area than they do now.

Dr. Du Riche Preller said that, to take an instance, the range of the Alps represented an upward thrust of roughly 4 miles in vertical depth, equal to about 0·1 per cent. of the radius of the Earth. He asked the Author whether, in support of his theory, he assumed that the upheaval of the Alps was simply compensated by a corresponding sinking of 4 miles somewhere at the bottom of the sea. The speaker contended that the Alps were the result of lateral, horizontal pressure from north and south, which continued in post-Cambrian and down to Tertiary times; and, contrary to the Author's theory, they were, like all mountain-ranges, due to comparatively local folds produced by shrinkage of the earth's crust.

Prof. Hull admitted the Author's view that the temperature of the outer crust had probably reached its normal state in Cambrian times, but was unable to see how the phenomena of flexures and foldings of strata, of faults, and of the fan-shaped structure of some mountains could be accounted for, except on the supposition of a somewhat rigid crust resting on a molten and continually contracting interior magma. If, as all observations proved, the internal heat was constantly being given off by conduction, or convection, there must be simultaneous contraction of the interior magma. This contraction would have the effect of bringing into play the tangential forces of the outer crust which had arrived at a normal condition of temperature, resulting in plications and similar phenomena. He thought that a diminution of temperature by one degree of the interior magma would produce in a spheroid such as

that of the globe an amount of contraction which would require a large amount of flexuring of the crust in order to establish equilibrium.

The Rev. Edwin Hill said that such a shrinkage would produce no difference of any consequence in gravity or air-pressure.

The Author, in reply, said that his estimate of a contraction of horizontal extension by folding was on the assumption of a contracting globe causing rock-folding, the assumption which he opposed, and that therefore the remarks of Prof. Hughes were practically in support of his views. Cooling and shrinkage before the Cambrian period, in reply to Prof. Hull, were not denied; but he thought he had shown that since that epoch no appreciable cooling or shrinkage of the globe had taken place, that therefore the mean radius of the planet had not decreased, and that as a consequence the foldings and plications of the Cambrian and post-Cambrian rocks had not been the result of the secular cooling and consequent contraction of the globe.

14. *The* Lower Greensand *above the* Atherfield Clay *of* East Surrey. By Thomas Leighton, Esq., F.G.S. (Read December 19th, 1894.)

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I. Introduction.

The district to which this paper refers extends from Leith Hill in the west to Tilburstow Hill in the east, and the beds more particularly discussed are those which have been described by the Geological Survey as the Hythe and Sandgate Beds. I exclude the Atherfield Clay from consideration here because, although rarely exposed in the district, it is so distinct in itself and of such persistent occurrence at the base of the series, that there can be no reason for doubting its position as mapped. Many geologists have treated of this district in the past; amongst the chief are Mantell,[1] Fitton,[2] T. Webster,[3] Murchison,[4] Mr. C. J. A. Meÿer,[5] and Mr. F. Drew with Mr. W. Topley.[6] The Weald Memoir of the Geological Survey prepared by Mr. Topley, so far as this district is concerned, chiefly from the notes of the late Mr. Drew, sets forth what may be called the hitherto accepted view of the Lower Greensand succession. That view is, that the northern outcrop of the series (as here limited) in the Weald is divisible into three sets of beds, named respectively the Hythe, Sandgate, and Folkestone Beds, which are mapped more or less continuously from the typical areas after which they are named. This view would no doubt have sufficed, but for the new light thrown on the question in 1885 by Dr. G. J. Hinde's paper 'On Beds of Sponge-remains in the Lower and Upper Greensand of the South of England.'[7] It should be remembered that Mr. Topley's memoir is dated 1875, and is based upon surveys made very much earlier, long before the promulgation of the existing views as to the origin of chert. Great praise, then, is due to the late Mr. Drew, since his work in the district is so well set forth that a geologist who is familiar with the country has only to recognize that the references to sandstones about Leith Hill and Wotton refer to the sandy cherts, and he will find the Survey Memoir correct in all

[1] 'A Sketch of the Geology of the County of Surrey,' Brayley & Britton's 'History of Surrey,' 4to. 1841.
[2] Trans. Geol. Soc. ser. 2, vol. iv. pt. ii. (1836) p. 103.
[3] *Ibid.* ser. 1, vol. v. (1821) p. 353.
[4] *Ibid.* ser. 2, vol. ii. pt. i. (1826) p. 97.
[5] Geol. Mag. 1866, p. 13.
[6] Mem. Geol. Surv. 'Geology of the Weald,' 1875.
[7] Phil. Trans. Roy. Soc. vol. clxxvi. (1885) p. 403.

respects, so far as it goes. Of course many new sections have been opened since 1860, whilst at that date the significance of the cherty veins in the sandstone was not understood. Where Drew refers to chert he appears, always so far as I have observed, to mean the compact, massive chert mentioned by Dr. Hinde (p. 405 of his paper) as forming the central layers of the sponge-beds.

There is considerable difficulty usually in obtaining a correct knowledge of isolated sections in this country, the dip is often uncertain from the amount of false-bedding, very few of the beds make regular features, and even where they do so, for no considerable distance; hardness, except in a few cases, such as that of the thick cherts of Leith Hill, appears to be due chiefly to local causes.

I have endeavoured somewhat to make way for the present discussion by two papers recently contributed to the 'Proceedings of the Geologists' Association,' in both of which papers, for the sake of clearness, the accepted names of the different beds were used. The first paper, read in December 1892, by Mr. G. S. Boulger and myself on 'The Lower Greensand Area between Wotton and Dorking,'[1] corrected a slight error in the map of the Geological Survey in that district, and protested against the correlation of the cherty sandstones of Wotton with the ironsands to the east. The main point of that paper has remained unchallenged. The second paper, published in November of last year, was a report on an 'Excursion to Abinger,'[2] conducted by myself, and described the wide spread of the Bargate Beds over the cherty sandstones on the northern slope of Leith Hill.

The object of the present paper is to show:—

(1) That the chert-beds of Leith Hill and the area to the west have been denuded from the country south of the present Lower Greensand escarpment south of Dorking, and that therefore, instead of a lithological change from east to west, as claimed by Frederic Drew,[3] we have a lithological change from south to north, from deep-water beds to shallow.[4]

(2) That at the base of the Folkestone Sands an area of pebbles

[1] Proc. Geol. Assoc. vol. xiii. (1892) p. 4. [2] *Ibid.* (1893) p. 163.

[3] Mem. Geol. Surv. 'Geology of the Weald,' p. 121.

[4] [I do not use the expression 'deep-water beds' in any sense as 'pelagic,' and, in deference to the discussion on this point, would gladly substitute any other formula which would convey the idea that between the southern end of Leith Hill and Dorking there is on the upper part of the horizon described by the Geological Survey as Hythe Beds (*i. e.* the entire Local Groups Nos. 2 and 3 of this paper) a change from 'a series of sponge-beds with some sand' through 'a series of sands with sponge-beds' (the latter decreasing northward in number and thickness) to 'a series of false-bedded clayey sands and sands'—the two series first mentioned being almost invariably without false-bedding. Drew noticed the rarity of false-bedding in his Hythe Beds of this country (Weald Memoir, p. 121), and in looking up this reference I have but now discovered that the place (near Collickmoor Farm) where he calls attention to the fact is close to the section at Boar Hill, to which I have here pointed, on other evidence, as showing intermediate conditions. In contradistinction to this series are the overlying highly false-bedded grits or pebble-beds of the acknowledged Bargate Series, showing conditions still more littoral. —January, 1895.]

with pebble-beds can be traced, all the way from Leith Hill to Tilburstow Hill, the pebbles becoming smaller, but their vertical spread wider, in their passage eastward.

(3) That these facts, and others which will be mentioned as the sections throughout the district are described, show that the Lower Greensand of this area consists of beds formed in a marine estuary or narrow sea, within the influence of strong currents, not far from land, and deepening from N.W. to S.E., so that no correlation with beds at Hythe and Sandgate is possible.[1]

For the sake of clearness and easy reference, I have numbered the groups of beds developed locally throughout this area of the Lower Greensand. These are[2]:—

Local Group No. 1.—The Fuller's Earth Beds with the associated limestones, sandstones, and cherts, between the Folkestone Sands and lower pebble area, between Reigate and Tilburstow Hill.

Local Group No. 2 (consisting of an upper and lower division).—The chert-beds of Leith Hill and the country to the west. The upper

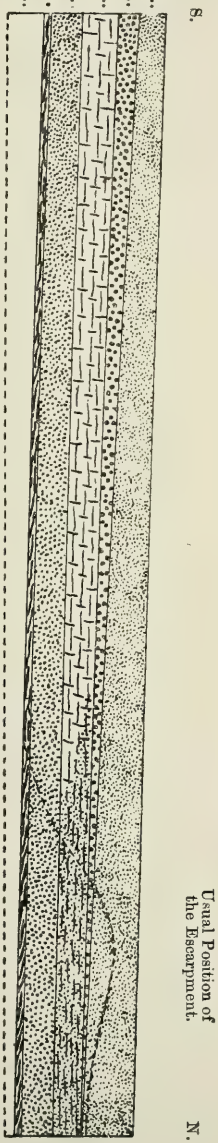


Diagram to illustrate the deposition of the Lower Greensand in East Surrey.

[1] [In deference to the discussion on this point, I would draw attention to the absence or thickness, as the case may be, of the Lower Greensand, as recorded in the Memoirs of the Geological Survey and elsewhere, under London, at Dover, at Folkestone and Hythe, round the South Downs, in the Isle of Wight, at Punfield, at Worbarrow, and near Devizes. The position of the Streatham boring, where the Lower Greensand is absent, lies 12 miles due north of the outcrop of that series north of Nutfield, which again lies 5 miles north of the southernmost part of the area dealt with here.—January, 1895.]

[2] [In deference to the discussion on my use of local names for the short quotation of beds locally developed, I have willingly substituted a system of numbers. These numbers, however, must not be taken to imply superposition; *they are only for the purpose of short quotation.*—January, 1895.]

division consists of sandy cherts which do not appear to have been formed in such deep water as the massive beds of the lower division.

Local Group No. 3.—The clayey sands seen to the south of Dorking.

Local Group No. 4.—The ironsands which overlie the Atherfield Clay at the base of the series, throughout the whole of this district.

II. The Chert-beds of Leith Hill.

In the light of Dr. Hinde's discoveries,[1] it has been open to any reader of pp. 121–123 of the Weald Memoir to suggest the probability of a north-and-south change in the so-called Hythe Beds, from littoral to less littoral conditions, both being overlain by the Bargate Beds; but since the Geological Survey claims [2] that there is a change in composition on this horizon between Dorking and Leith Hill, it appeared to me to be essential to controvert that statement before proceeding to any suggestion whatever.

There are several exposures of the various beds of the Lower Greensand upon Leith Hill,[3] and I give the following vertical section as a general collation of them all:—

Folkestone Beds. Ferruginous sands, much false-bedded, with layers of Carstone (usually most plentiful in the lowest beds	10 feet seen.
Junction-beds. (*a*) Ferruginous sand with comparatively large pebbles (lydites, quartz, etc.)	1 foot ?
(*b*) Dark glauconitic sand, strongly false-bedded, with layers of ferruginous sand, containing scattered smaller pebbles similar to those in (*a*)	3 feet.
Bargate Beds. (*a*) Dark glauconitic, pepper-and-salt coloured sands, pebbles rare; at times clayey, and with thin layers of clay and clayey sandstone	3 to 6 feet.
(*b*) Calcareous grit-beds of the usual Bargate character, with pebbles (lydites, quartz, etc.)—the grit varies very much horizontally and vertically in coarseness and in hardness, and finally passes downward into coarse calcareous sandstone, interbedded with calcareous sands. Fossils occur in the upper beds chiefly, and near the top are some thin layers of greasy clay. (No loose beds of pebbles, properly so called.)	25 feet.
Junction-bed. Ironstone and sandy chert	1 foot to 3 inches.
Hythe Beds of the Geological Survey (Local Group 2). *Upper division.* Rubbly beds of sandy chert interbedded with layers of glauconitic quartz-sand—olive-white in colour throughout—with occasional bands of massive brown chert, thickening generally downward	60 feet to N.
Lower division. Massive greensand and chert; varying in character, but generally containing thick beds of hard rock, with softer beds of sandstone and sandy chert in places; sometimes sharply defined from the beds above, but at others passing into them	80 feet to S.
Hythe Beds of the Geological Survey (Local Group 4). Ferruginous sands	100 to 130 feet.

[1] Phil. Trans. Roy. Soc. vol. clxxvi. (1885) p. 403.

[2] 'Geology of the Weald,' 1875, p. 121.

[3] [The name 'Leith Hill' is here applied to the whole physical feature, not particularly to the southern point of that feature, which is a common resort of pleasure parties. This application of the name is in accordance with local usage, besides being scientifically and topographically correct.—January, 1895.]

The sections about Abinger are described in my paper already referred to. The cherty sandstones and sands seen at Raikes Lane, Raikes Hollow, Abinger Lane, Wotton Lane, Coast Hill, at the surface near the tower on the top of Leith Hill, and at the upper part of the pit above Abinger Bottom, belong to the upper division of Local Group 2. In the last pit named the junction of the upper and lower divisions is seen, and it is there clearly defined, but I do not imply that that is always the case. In dividing the beds of Leith Hill into an upper and lower group, I wish only to say that the higher horizons consist of the rubbly beds of sandy chert, while more massive beds come in below; it is not at all clear to me that the division is at a constant horizon. This question is almost hopelessly complicated by the peculiar effects of surface-weathering upon chert: rubbly beds are always, so far as I have observed, seen near the surface, and at least it cannot be proved that beds so situated in the exposures on the east of Leith Hill, where lower horizons crop out, are not the result of surface-action. I have referred to this difficulty in a former paper[1] and shall have to do so again later on here. There can be no doubt, however, that the rubbly beds are distinctive of the higher horizons in all the sections just mentioned.

Characteristic sections of the lower division of Local Group 2 may be seen, besides at Abinger Bottom, at the pit near Coney Wood opposite Woodhouse Farm, at the old quarry above Coldharbour, and at Boar Hill. There are other sections in both divisions, but those noticed here are the important ones. The beds of massive greensand of the lower division appear to be spicular in a high degree, which probably accounts for their hardness. Casts of spicules, and I think spicules also, may even be seen in freshly-broken specimens, whilst old weathered specimens from Coldharbour yield most beautiful examples of the sponge-origin of these beds. Drew mentions the purple-coloured beds in this quarry[2]; these appear to consist almost entirely of sponge-remains (the colour, I think, is due to peaty stain).

The beds of Local Group 4, ironsand often very like the Folkestone Sands, may be seen on the east of Leith Hill at the 700-foot contour in Redlands Wood, on the ascent from Holmwood Common by way of Folly Lane. The best exposure is, however, under the tower at the highest point of the hill. At least 100 feet of sand is seen here, and I estimate the total thickness of these beds at between 100 and 130 feet, but it is difficult to speak with any certainty, on account of the slips. The sands are compacted into soft sandstone on certain horizons.

From 90 to 100 feet of cherty beds cap the sands at the top of Leith Hill (under the tower). The thickness here given to the lower chert-beds is arrived at by careful comparison of the levels at the southern end of the hill. As much as 60 feet of the upper cherts is seen at Coast Hill, the exposures about Abinger show rather less, but the thickness here given to the Bargate Beds is seen about Abinger, and the junction of the last with the Folkestones is the

[1] Proc. Geol. Assoc. vol. xiii. (1893) p. 141.
[2] Mem. Geol. Surv. 'Geology of the Weald,' 1875, p. 121.

section in Abinger Lane. It is not contended that the whole thickness given to all the beds of this collated section was ever regularly superimposed at any one place. I am of opinion that the beds of Leith Hill show thickening of deep-water deposits to the south; nevertheless, whilst there is nothing to show that the whole 60 feet of the upper beds may not have existed at the tower before denudation, there is some evidence that the massive chert-beds decrease very much in thickness to the north.

In many places there is evidence that the whole of the beds of Leith Hill incline west as well as north; this is clearly brought out, however, by a comparison of levels about the parallel N. 51° 12′ 30″. At Damphurst Hollow, the top of Local Group 2 crops out hereabouts close under the 500-foot contour; in Wotton Lane to the west the 400-foot contour must lie about 50 feet down in the cherts (a fall of 50 feet), but in Raikes Lane at 380 O.D. we must be much higher up in that series, if not at the junction with the Bargates (a fall of 20 feet). Between the first and second of these places the beds are no doubt affected by the north-and-south fault at Abinger Bottom, although that lies a little to the south; but there does not appear to be any such disturbance between the second and third. This rise of lower beds on the east of Leith Hill lends a special interest to the section at Boar Hill, where at 560 O.D. a cutting has recently been made towards the field-path leading to Collickmoor Farm. The beds show a high dip arched over to the west, and contain sandy cherts above, then beds of the massive greensand 2 to 3 feet thick, with beds of soft sandstone, loose sand, and thin clays, in bedded layers below.

The sandy area of the Lower Greensand immediately north-east of Leith Hill is sufficiently described eastward, as far as and including the sections along the Horsham Road, in the paper by Mr. Boulger and myself already referred to. An interesting fact has come to my knowledge this autumn, however, through a slip in the sandpit at the 300-foot contour on the Horsham Road, Section (C) of that paper.[1] I was able, by means of this slip, to reach the top of the section, where I found a well-developed bed of grit with pebbles (the usual lydites, quartz, etc.) in a dark sandy matrix, which I think there is little doubt must be the bed mentioned by F. Drew on p. 134 of the Weald Memoir as having been useful to him in mapping the base of the Folkestone Series hereabouts. This is an extremely interesting discovery, because in our paper the base of the Folkestone Series was drawn here upon altogether different evidence. This bed has, I believe, been taken as the base of the upper member of the Lower Greensand by all recent writers; and particular attention is drawn to it now, because it corresponds so exactly with the bed at the same position in the series in the junction-pit in Abinger Lane,[2] and because it will be referred to again later on. A bed of grit with similar pebbles occurs some feet

[1] Proc. Geol. Assoc. vol. xiii. (1892) p. 6.
[2] *Ibid.* p. 166; Quart. Journ. Geol. Soc. vol. l. (1894) p. 729.

up in the Folkestone Beds at the 'Rookery' section, but the matrix there is the usual Folkestone Sand, and the exact horizon of this bed, beyond that it is close to the base of the series, cannot be ascertained.

Passing to the east from the Horsham Road, sections through the sandy area are to be seen in Chart Lane and in Punchbowl Lane. In the former lane the section corresponds almost exactly with that on the Horsham Road and is capped with drift, of which I shall speak presently. I have been much struck by the changes which the sections in these hollow lanes undergo within a short period. Slips occur in the winter, and sections are open during one summer which are spoilt and overgrown by the next. During the last three years, however, I have at various times noted the clayey sands with the layer of phosphatic nodules (Local Group 3) above the junction of Chart Lane with New Road, the nodules occurring exactly at the top of the hill. These beds were nowhere visible last summer, but a little higher up in the series pebbly grit in a dark sandy matrix was beginning to appear, with every prospect of a good exposure shortly. To the south, the ironsands of Local Group 4 are seen, before the horizon of the Atherfield Clay is reached.

A similar but more interesting section is exposed in Punchbowl Lane. Exactly 1 furlong south from the Reigate Road at about 280 O.D. there is, in the west bank of the hollow lane, a fine exposure of the pebble-bed in a dark sandy matrix, quite of the usual character, fairly hard in places, highly false-bedded, with lydites and quartz and other pebbles (including pebbles of clay), corresponding in all respects with the exposures already mentioned to the west (pp. 104, 106). This bed is seen to underlie typical Folkestone Sand, but the beds which immediately underlie it are not exposed. Since F. Drew draws a certain line for the base of the Folkestone hereabouts,[1] I have little doubt that this is the section from which he worked, although by the modern maps he would appear to have drawn the line about $\frac{3}{4}$ furlong too far south. Considerable margin, however, must be given by a man working with the existing 6-inch maps to one who had only the old edition on the 1-inch scale.

It is worthy of notice that the three observations here made of this bed in the three lanes give a line which runs fairly parallel with the outcrop of the Atherfield Clay up to the point where that outcrop is cut off by the 'Rookery' fault. To the east of Punchbowl Lane the lower horizons of the Lower Greensand sink beneath the alluvium and gravels of the Mole, and there are no further noteworthy sections; but the southern end of this hollow lane shows slightly clayey sands over the beds of Local Group 4 (both capped by drift) just before the outcrop of the Atherfield Clay is reached.

The chief interest of this district is in the drifts which I have twice mentioned as capping the beds of the sandy area. Dr. Hinde refers in his paper[2] to the occurrence of fragments of chert at the

[1] Geol. Surv. Map, Sheet 8, Drift Edit.
[2] Phil. Trans. Roy. Soc. vol. clxxvi. (1885) pp. 406, 409.

surface over various parts of the Lower Greensand outcrop, and suggests that they have been let down from beds otherwise denuded. Without doubt that is a correct explanation in many places, but it cannot be so here, since it has been shown by F. Drew,[1] as well as myself, that the beds of this district are sandy throughout.

It is true that, on p. 121 of the Weald Memoir, Drew notices that 'in Betchworth and Deepdene Parks there is some sandstone' (by which I understand from his other references 'cherty sandstone'), but I do not think that this could have been *in situ*,—

(1) Because the base of the Folkestones, as corrected by the 6-inch map, places nearly the whole area of these parks within the upper division of the Lower Greensand; (2) because the chief exposure of the chert-drift is in Deepdene Park over Folkestone Beds; and (3) because I should be glad to be able to state certainly that cherts occurred in the lower beds here, but am unable to do so.

The extreme difficulty of determining whether the cherts are *in situ* or not, from small exposures near the surface, has been referred to above (p. 105), and, having once been found in the wrong,[2] I have need to be extremely careful now. In October, 1893, I noticed a bed of sandy chert about 6 inches thick in the buff sands near the southern end of the Lower Greensand outcrop in Punchbowl Lane, close to the B.M. 312, which then appeared to be *in situ*. It seemed to give the required evidence of the thinning-out of the cherts in this direction, and since the position lies between Deepdene and Betchworth Parks, if correct, it would have confirmed Drew's observation.

I still incline to the opinion that the bed was *in situ* when the observation was made, but in the autumn of 1894 it had altogether the appearance of having been let down in the way suggested by Dr. Hinde,[3] or at least a portion of it had that appearance, for it was associated with other loose drift. Of course, the appearance referred to may have been brought about by the slipping of the bed down the slope. The rapidity of such changes has been already noticed here (p. 107), and but for the associated drift, which I did not notice before, I should now be able to speak with certainty. Whatever may be the history of the bed in question, it cannot controvert my argument, because,—

(1) If the bed is *in situ* and Drew's observation is correct, it only proves my view of the northerly thinning of the chert; (2) if it has simply been lowered by denudation, it provides me with the same evidence; and (3) if it is true drift, it becomes only another link in the evidence afforded by other drifts at higher and lower levels.

The surface of the escarpment about Glory Wood is strewn with pieces of chert; and in Chart Lane, between the entrance to Deepdene Park and the top of the hill, from 8 to 10 feet of drift lies upon an extremely uneven surface of the Folkestone Beds. The bottom

[1] 'Geology of the Weald,' 1875, p. 134.
[2] Proc. Geol. Assoc. vol. xiii. (1893) p. 141.
[3] Phil. Trans. Roy. Soc. vol. clxxvi. (1885) p. 406.

of the drift has been worked into the loose sands, channels of it apparently passing right into them. The drift consists entirely, so far as I have observed, of Lower Greensand material; towards the bottom it is mainly rough angular chert, often in large pieces. There are also lenticular beds of grit, chiefly Bargate débris. One of the specimens exhibited is a block of chert which has Bargate débris, with the cast of a bivalve, adhering to it. In some places sandy brick-earth overlies the rougher drift, there are lenticular beds of sand throughout, and generally the drift may be said to be coarser and rougher in the lower layers. Farther south, in Chart Lane, below the junction of the New Road, drift with chert is seen, over the sandy beds; this, although 12 feet thick in places, appears to be, properly speaking, the 'run of the hill'; it consists of sandy brick-earth with scattered fragments of angular chert. A similar but smaller 'run' appears to pass down the northern slope of the hill also.

The drift *in situ* lies at the highest part of the escarpment; Glory Wood is above 400 O.D., the section in Chart Lane about 370 O.D. A similar drift, only less rough and with the Bargate pebbles more generally distributed, is seen in Punchbowl Lane at 306 O.D., at the junction of the bridle-path to Park Farm. It lies on an uneven surface of the buff sands, 100 yards to the south of, and 6 feet below the level of, the doubtful bed of chert already referred to. This gravel has all the appearance of having been, like the higher one, deposited by running water, and it is clear that, since both beds must belong to the past history of the Mole, the material of which they are composed must have been brought from the country to the south, and that therefore the chert-beds and overlying Bargates formerly existed there.

The evidence does not end here, however, for the surface of the country to the south is strewed with chert-débris, and the alluvium of the brooks flowing thence into the Mole is full of it.

Taking the waterways first, chert in plenty may be found in the beds of Bent's Brook and the Black Brook; in Tanner's Brook at Brockham the pebbles are chiefly from the Wealden Beds, but large, partly sunken blocks of chert may also be seen. In the Mole under Box Hill, that is, east of the gap in the Chalk escarpment, the chert occurs within the Vale of Holmesdale; it also may be seen, associated with Bargate débris, in a small exposure of high-level river-drift, over the Folkestone Sands on the Reigate Road, a little east of Punchbowl Lane. This small section is capped by hill-wash, but the lower beds have clearly been deposited by a river.

The surface of the Weald Clay at Holmwood Common is strewed with chert-débris, and it is interesting to notice that the massive chert-beds have chiefly supplied the pebbles here, while those to the north are from the upper division. Chert-pebbles may be seen *in situ* in the soil over the clay, in a small section at the side of the road leading to the brickfield, west of Brookmeadow on Holmwood Common, while they accumulate and are gathered into heaps on the cultivated lands to the west.

Towards the foot of the escarpment of Leith Hill there is no

appreciable increase of chert-débris until the Horsham Road is passed. There is comparatively little chert-débris on the Holmwood slope of Leith Hill, more of course than on the common below, but still less than might be expected from the steepness of the scarp. It is to be remembered, however, that the ironsands of Local Group 4 very largely form the escarpment on this side, rising over Folly Lane, as has been stated, to the 700-foot contour, that is, within 86 feet of the highest point of the easternmost ridge.

III. The Pebble- and Chert-beds East of Dorking.

About a mile east of Dorking the Lower Greensand ceases to form an escarpment for a distance of between $2\frac{1}{2}$ and 3 miles, owing to its line of strike being occupied by the valley of the Mole. This stream, aided by atmospheric agencies, has planed down the country to an average level of about 200 O.D., so that sections are hardly to be expected. The Folkestone Sands are seen at times towards the north of the outcrop, but there are unfortunately no sections of the lower beds until the escarpment begins to rise again at the east side of the gap, close to Reigate.

At Trumpetshill, south of Reigate Heath, just where the escarpment may be said to commence, the ironsands of Local Group 4 are seen in a pit at 215 O.D. They are the usual false-bedded ironsands, but contain a few small scattered lydites and pebbles of quartz. North of this place, at the south-western corner of Reigate Heath, about 250 O.D., there is a second section, possibly also in the same beds. It is impossible to say certainly from this isolated section to which sub-stage these sands should be referred. They are mapped as Hythe by the Survey, and their position certainly appears to place them more probably on the horizon of Local Group 4 than on that of the Folkestone Beds.

At Reigate Park, however, we arrive on more certain ground; the surface here rises to about 400 O.D., and the following striking section is exposed in Bell Street, opposite the New Road, at 317 O.D. Dip N. (about 5°):—

Sand, with layers of chert, obscure as to the sand	4 feet seen.
Pebble-beds, soft olive-white sandstone, giving a wall-like section, with lydites, pebbles of quartz, etc., and pebbles of clay	7 feet.
Dark coarse sand, much false-bedded	2 feet seen.

Great interest attaches to this section; its position in the series can be ascertained, and while it agrees in the main with the new order of things seen at this horizon to the east, and all its divisions can be traced there, it also bears strong resemblance to beds on the same horizon to the west; it serves, in fact, as a link connecting the two. The beds of the Bell Street section almost immediately underlie the Fuller's Earth, which again underlies the Folkestone Sands; this is clearly shown on the Geological Survey map, and on the ground the correctness of that mapping can be demonstrated.

In Reigate Park, to the south-west, the chert-beds may be seen in the footpath ascending the hill at the escarpment, about the 400-foot

contour; while a short distance south, at Woodhatch, the Atherfield Clay crops out in two places a little below the 300-foot contour. The levels of the two exposures of the cherts here give these beds a dip to north of 1 in 12 (quite a normal dip); and, calculating from that, we must have at least 160 feet of beds below, before reaching the top of the Atherfield Clay.

Quite apart from their intrinsic resemblance, the position of the Reigate Pebble-beds in the Lower Greensand approximates so closely to that of the Pebble-beds in the west, that there is no doubt in my mind as to their lying on the same horizon. To the south of Reigate Park, in Park Road, at 360 O.D., between 40 and 50 feet below the chert-beds in the series, ironsands with scattered small pebbles of the usual kind are seen; these sands are false-bedded, and have layers of Carstone. These are the beds of Local Group 4, and no doubt lie near the horizon of the section at Trumpetshill.

The next series of sections claiming attention is upon Redhill Common. At the northern end of the large upper pit there is the following section:—

Fuller's Earth (with a thick bed of ironstone in it)	4 feet seen.
Irony clay-beds, with Carstone and pebbles (lydites, quartz, etc.)	1 foot 6 in.
Drab-coloured sands passing into olive-brown sandstone (not calcareous, otherwise resembling Bargate Stone), pebbly throughout	2 feet.
passing into	
Pebble-bed; hard loamy sand or soft sandstone, giving a wall-like section with larger pebbles (lydites, quartz, etc.), pebbles of brown clay, and clayey pipings of contemporaneous origin; light drab in colour, but sometimes stained with iron, the lower 6 inches usually so; with occasional layers hardened into Carstone	2 feet.
passing into	
Glauconitic sands, coarse and false-bedded and with layers of Carstone, with small pebbles as usual (lydites, quartz, etc.)	2 feet seen.

[Dip N.; all the beds vary somewhat in composition horizontally.]

All the beds below the Fuller's Earth may be described as 'Bargate'-like, but are without calcareous matter. Although there is no chert here between the Pebble-beds and the Fuller's Earth, it is obvious that these are the same beds as those seen in Bell Street, Reigate. The beds just tabled can be followed southwards along the pit as sections occur, they run out in succession at the surface, and in the high section at the south end of the pit are seen to be underlain by coarse, false-bedded, buff sands and grits, with the usual pebbles and layers of Carstone (full 30 feet seen). These beds are again underlain by beds of brilliant crimson-mottled sands, which appear to be peculiar to this locality and may have given it its appropriate name. These sands very much suggest a lacustrine origin.

Immediately south of, and below, the pit just described, there is another pit on the high road to Brighton in which the coarse, false-bedded, buff sands overlying the compacter crimson-mottled sands

are again seen at a level 50 feet lower. As the Atherfield Clay crops out in the valley below, I take this repetition of beds to be occasioned by a big slip or 'escarpment-fault' which probably conceals the white, sometimes calcareous, sands seen in the section on the main line of the L.B. & S.C.R. on the opposite side of the valley. These white, sometimes calcareous, sands and sandstones will be referred to presently (pp. 113, 115, etc.).

From want of connecting evidence the succession here is rendered somewhat obscure, but I believe that the explanation which I have given is the true one. Neither pit on Redhill Common is now worked, so that, on account of the slopes, it is difficult to estimate the thickness of the two sands. However, of the coarse, false-bedded, buff sands at least 30 feet is seen, and of the crimson-mottled compact sands at least 20 feet. The pebble-bed on Redhill Common crops out at about 420 O.D., or at least 100 feet higher than at Bell Street, Reigate, but the latter section lies a little south of the parallel. A fall of all the beds hereabouts towards the west will also connect the coarse, false-bedded, buff sands (with beds of grit and pebbles) of the south end of the upper pit on Redhill Common, with the similar exposures in Park Road and at Trumpets-hill, Reigate.

My view of the succession at Redhill is further supported by the fact that just to the east of north of the common, striking N.N.E.–S.S.W., is the Merstham fault with downthrow to the west—a sharp dip to west immediately south of such a fault is only to be expected. Accepting this view of the succession as correct, we have another opportunity of roughly estimating the horizon of the Pebble-beds of Redhill, by the levels respectively of their outcrop and of that of the Atherfield Clay. In the valley below the common the top of the Atherfield Clay crops out at 250 O.D. or thereabouts, or 170 feet below the Pebble-beds. The outcrop of the Atherfield Clay lies a little south of that of the Pebble-beds, but allowance must be made for a probable slight anticlinal along the continuation of the line of fault, of which indeed the dips recorded on the Geological Survey map afford some evidence.

Before proceeding to consider the sections to the east, it will be well to say something concerning the present position of the discussion as to the correct horizon of the Fuller's Earth Beds around Nutfield. The opinions of the pre-Survey writers need not detain us now, as they were fully set forth by Mr. Topley in the Weald Memoir, and by Mr. Meÿer in his paper of 1866. My reason for passing over the opinions of these early writers here by no means arises from want of appreciation of the work that they have done in assisting to elucidate these difficult sections; in addition to the reason stated above, it is to be noticed that they make no mention of the Pebble-beds, and their occasional references to the Chert-beds are difficult to identify.

Mr. Meÿer, I believe, first called attention to the Pebble-beds in this district in his paper in the Geological Magazine for 1866 (p. 16). The section which he gives is the one in the lane leading to Little Cormonger's Farm, without doubt the same section as that quoted

by Mr. Topley on p. 132 of the Weald Memoir; this section is still to be seen, and will be mentioned here in its proper place (p. 115). It is evident from Mr. Meÿer's remarks in the paper just referred to that he was acquainted with other sections in the hollow lanes of this district, but he gives no details. In the same way, on p. 19 of his 1868 paper 'On the Lower Greensand of Godalming,' printed by the Geologists' Association, he refers, without details, to 'Pebble-beds' near Dorking, possibly one of the sections described in § II of this paper. From these sections of the Pebble-beds Mr. Meÿer places the Fuller's Earth of Nutfield at or near the base of the Folkestone Sands, and almost on the horizon of the Bargate Stone at Godalming.[1] The beds of stone overlying the Fuller's Earth he considers to be the equivalent of the Folkestone Stone-beds; the coloured sands below the Pebble-beds at Nutfield he calls Sandgate Beds, and certain white sandstone-beds below them, the Hythe Beds.[2] In the various sections given below it will be seen where I differ from his interpretation.

The Weald Memoir of the Geological Survey, although published in 1875, is (as already stated) based upon F. Drew's notes made about 1860. Full justice is there done to Mr. Meÿer's views, but Drew's reading of the beds is adopted: that is, the Fuller's Earth and overlying Stone-beds are described as Sandgate, the iron-sands above the Stone-beds as Folkestone, and the lower beds (described chiefly as sands) Hythe. The division between the so-called Sandgate and Hythe Beds is not stated; in fact on p. 132, in the description of a section by Mr. Whitaker, that author queries whether the bottom bed of his section belongs to the Hythe, while Mr. Topley immediately afterwards suggests that possibly the two highest beds in a lane just south of Mr. Whitaker's section may belong to the Sandgate. My reason for noticing this is, that it is the same series of sections, referred to above, as those which Mr. Meÿer described in 1866, and that gentleman's description is the better of the two. As a matter of fact the 'layers of sandstone, passing under high road and forming floor of Fuller's Earth pit' (Folkestone) of Meÿer, the 'soft sandstone touched below' (Hythe?) of Whitaker,[3] and the 'layers of sandstone' (possibly Sandgate) of Topley,[3] are a series of sandy chert-beds which everywhere throughout this district (but becoming thicker westward) lie between the main bed of Fuller's Earth and the Pebble-beds—as will be seen later on (pp. 115, 116, etc.). About Tilburstow Hill the Geological Survey places the chert-beds with the Hythe,[4] while I find no mention whatever of the white sandstones (referred to by Meÿer on p. 16 of his paper of 1866 as the highest layers of Kentish Rag).

Speaking generally, the study of the more recent literature gives the reader the impression that in the Nutfield–Blechingley district the horizons of the Lower Greensand now under discussion consist of a variable series of beds without definite order. My examination of the country does not lead to that conclusion; on the

[1] Geol. Mag. 1866, p. 15.
[2] *Ibid.* p. 16.
[3] Mem. Geol. Surv. 'Geology of the Weald,' 1875, p. 132.
[4] *Ibid.* p. 120.

contrary, I hope to show that the different beds can be followed (although new features appear as one proceeds westward) from section to section, and that there is a regular order of superposition.

I left the detailed description of this district at the main line of the L.B. & S.C.R. at Redhill. Immediately east of the railway, and at several other places between Redhill and Nutfield, the Fuller's Earth is worked. The sections described in the Survey Memoir are generally similar to these[1]; the main bed of Fuller's Earth is at the bottom of the series, but above that thin beds sometimes alternate with the beds of stone (this is shown in the sections given in the Survey Memoir, and can be seen in the Patteson Court pit now open at Redhill). At Tilburstow Hill a thin bed of Fuller's Earth underlies the main bed, and although I have not seen other instances, they may of course occur.

The stone-beds overlying the main bed of Fuller's Earth, and alternating with thinner beds, are beds of massive greensand, sandy limestone, soft sandstone, and hardened sands, the sandstones often calcareous; in some places these beds are fossiliferous.

I have not observed any regular chert-beds at this horizon, but sponge-remains occur, since Dr. Hinde on p. 407 of his paper mentions at Nutfield 'grey sandstone, filled with spicules.' Perhaps my usual luck has deserted me here, but I have found a soft sandy limestone or calcareous greensand with spicules, which sufficiently answers to Dr. Hinde's description. Some of the sandstone-beds contain nodular inclusions which may be sponge-remains. These are very different rocks, however, from the ordinary beds of sponge-remains.

A short distance to the east is the important series of sections at the Cockley Fuller's Earth Works, Park Fuller's Earth Works, and in the lane thence south to Little Cormonger's Farm, mentioned as before stated (p. 113) by Meÿer, Whitaker, and Topley. I am able to add a few points of interest to what has been already said on these sections. At Brooker's Barn, in the extreme north of the now-abandoned pits of the Cockley Works, the junction of the stone-beds with the ironsands of the Folkestone series is seen. Above the soft sandstone and calcareous greensand-beds is a Pebble-bed with small lydites, pebbles of quartz, etc., in (usually) a dark glauconitic, sandy matrix, but sometimes the latter is slightly loamy. This stratum is highly false-bedded. Above it are the ironsands, somewhat glauconitic, and containing courses of stone full of sponge-spicules and casts of fossils, with occasional pebbles. The sands and courses of stone are both strongly false-bedded. The western face of the pit to the south, under the 400-foot contour, close to the high road, gives the following section:—

Soil and red sand	4 feet.
Iron-sandstone	6 to 8 inches.
Stone-beds—hardened calcareous greensand and soft sandstones; blue and cream-coloured, with sometimes dark clayey inclusions; certain beds with sponge-spicules	26 feet seen.

[1] 'Geology of the Weald,' 1875, pp. 131–133.

The southern face of the same pit shows 16 feet of blue Fuller's Earth below the series of beds last mentioned. Beyond the next field to the east are the Park Works, where the Fuller's Earth is worked at the surface on the 400-foot contour. This is the pit referred to by Meÿer and Whitaker, and in the lane to the south is the section mentioned by Meÿer and Topley. The 'layers of sandstone' of Meÿer I have already said are chert-beds, but I can add nothing to that author's description of the underlying Pebble-beds, which are well shown now at the junction of Sandy Lane. For Meÿer's next beds 'light ash-coloured and ferruginous sands becoming slightly argillaceous as they descend, 50 to 100 feet,' I can give the following section (somewhat imperfect owing to the unsatisfactory condition of the cutting):—

Mottled buff sands, becoming clayey below, sand usually fine.	
Layer of sandy chert	6 inches to 1 in.
Buff clayey sands.	
White and grey glauconitic sandstone, with dark clayey inclusions; not calcareous so far as observed, but possibly belonging to the Kentish Rag. [Kentish Rag of Meÿer] (*a*).	

The last are the lowest beds seen in this lane, but where last exposed they are still 100 to 130 feet from the top of the Atherfield Clay, which lies between 200 and 230 feet below the Pebble-beds.

In this series of sections I describe everything between the Pebble-bed at the base of the Folkestones and the lower Pebble-beds, both inclusive, as Local Group 1, and hold that they are practically on the same horizon as the Bargate Beds of Godalming, thus in part agreeing with Meÿer. The sands below appear to me to belong to Local Group 4, possibly containing a northerly thinning of deeper-water beds, formerly laid down to the south.

At the farther end (east) of the village of Nutfield another hollow lane, termed on the 6-inch map Cooper's Hill, runs south, parallel to the one last described. Top of the section about 460 O.D., dip N.

White speckled cherty sandstone, with occasional suggestions of marked chert-layers, becoming rubbly near the surface	6 feet seen.
Olive-white pebble sandstone (pebbles with usual Bargate character), a well-marked bed	4 feet.
Pebble-beds—sands, hardened in places, much false-bedded, and containing layers of characteristic Bargate pebbles in sandy matrix—in places highly glauconitic layers, with few or no pebbles	10 to 12 feet.
Coarse false-bedded sands (Sandgate Beds of Meÿer[1]); at the top they differ little from the finer Pebble-beds, except that they are more uniform, are mottled red-and-white in colour, and do not contain pebbles	About 20 feet seen.

Lower down this lane false-bedded ironsands are seen in several places; they become finer and slightly clayey below, these characters generally increasing downward. The beds of Local Group 4

[1] Geol. Mag. 1866, p. 16.

appear to be of about the same thickness here as at the last place described, namely, 230 feet; no chert or white sandstone-beds are exposed, but ironsands are seen below the horizon where these occur in the lane to the west.

Continuing eastward, the next section is in the first hollow lane leading south from the village of Blechingley—the lane to Underhills, immediately east of the Castle. Top of the section about 500 O.D., dip N.

White glauconitic sandstone	1 foot.
Limestone, hard, grey, and glauconitic	1 foot.
Bedded clayey sands	2 feet.
Sands and cherty sandstones in bedded layers, yellowish-white in colour	8 feet.
Pebble-beds—false-bedded sands and soft sandstones—the usual Bargate pebbles and clayey pebbles in an olive-white glauconitic matrix[1]	5 feet.
Coarse, glauconitic, false-bedded sands	6 feet.
Atherfield Clay, estimated to be between 150 and 160 feet lower down.	

The next section is in Outward Lane, running south from Blechingley at the east end of the village. This section shows only Local Group 4, but it lies farther south than the exposures previously tabled. Before reaching the hollow lane, a platform made by the overlying chert-beds, etc. is passed over, about 450 O.D., apparently some 200 to 250 feet above the Atherfield Clay; the cherts and the overlying 1-foot grey limestone are exposed at the roadside. The following is the section in the hollow lane :—

	Top of section about 450 O.D., dip N.	
	Chert-beds (of Local Group 1)	Seen.
	Coarse buff ironsands	35 to 40 feet.
	Finer buff sands, clean in places, but usually more or less clayey (particularly low down in the series), with inclusions of dark clay, and partings of clayey sand and sandy clay	25 to 30 feet.
Horizon of Kentish Rag.	White and grey sands, sandstones, and thick sandy limestone (Kentish Rag-beds), with *Belemnites*, *Ostrea*, and other fossils; containing dark calcareous clayey partings and inclusions (most numerous on the lowest horizons); softer above than below; at the top are stratified sands, with buff and dark layers, capped by a bed of soft sandy limestone. The clay almost throughout this section is calcareous; I cannot say 'always,' as the section is rather overgrown and dirty	30 to 40 feet.
	Buff and red ironsands, mottled with whitish-grey clayey pipings (not calcareous)	3 feet seen.

The next lane to the east, Coldharbour Lane, shows sections above the 500-foot contour—nearly 50 feet of very coarse, false-bedded, glauconitic white and buff sands, with beds of grit containing minute Bargate pebbles.

Still farther east, about the same level, in the lane close to

[1] These are, no doubt, decomposed pebbles of granitoid rocks.

Rabbitsheath Cottages, a section facing south at the top of the escarpment shows the same beds capped by white sandstone with traces of chert; while, in the lane adjoining, the massive chert-beds are seen *in situ*. There is a small fault here with downthrow to the north, the exact junction being concealed by slope and underwood, but if the lines of the thick chert are carried on a few yards, at the dip which they show where exposed, they run into the sands.

This locality is close to Tilburstow Hill, where there are now six sections, three of these being in the plantation, approximately on one horizon, descending the slope to the south of the high road, and almost opposite the lane by Rabbitsheath Cottages. There are also two pits on Tilburstow Hill Common, and another in the plantation south of, and below, the escarpment to the west of the Roman Road.

The following section is shown in the upper pit of Tilburstow Hill Plantation; the lower pits show portions of the same series. Dip N.:—

Sandy Fuller's Earth	4 feet.
Calcareous clayey greensand (about equal proportions of glauconitic sand and clayey partings)	4 feet.
Sandy Fuller's Earth	8 inches to 1 foot.
Calcareous clayey greensand, as above described, but harder and with more sand—an impure, glauconitic, calcareous sandstone, capped occasionally by a 4-inch bed of hard, glauconitic, sandy limestone	5 feet 3 inches.
Beds of dark-blue or black calcareo-siliceous rock, interbedded in lenticular masses with glauconitic calcareous sandstone; the blue rock is often fringed with buff sandy limestone	7 feet.
Compact cream-coloured limestone	1 foot.
Repetition of blue rock and associated beds, as described above	3 feet seen.

The Fuller's Earth at the top of this section appears to lie in basin-shaped hollows in brown sandy clay, the whole lying on the next bed tabled. There is much clayey drift and soil above, so that the upper part of the section is rather obscure, but the thickness (4 feet) here named for the Fuller's Earth can be clearly seen. This section lies at about the 500-foot contour; almost due east of it, on the northern slope of Tilburstow Hill Common, at a level perhaps 50 feet lower, there is a small pit which shows

Drift, etc.	3 feet.
Rubble-sandstone, slightly cherty in places	5½ feet.
Sandy chert-beds of the usual character	5½ feet.

On the eastern side of the road-cutting south through the escarpment, still on the common, there is a large pit, which shows a section of about 70 feet, dip N. The section lies some 300 yards south of the parallel of the Plantation Pit, and is between 520 and 590 O.D. At the top there are sandy cherts, thin sandstones, beds of massive chert, and bands of ironstone, but the chief part of the section

consists of sands. These are whitish-grey and glauconitic. Below a well-marked line of chert is a bed of fairly compact greensand, then follow looser grey coarse sands (strongly glauconitic), so far as the slopes allow of observation, to the floor of the pit. Ironstone occurs along lines of infiltration throughout the lower beds, but this is quite a usual phenomenon in sandy and similar soft beds, and is probably of no stratigraphical moment.

A few score yards farther on, just through the escarpment, a gate on the west leads to a noteworthy section in a small plantation. The whole series of beds from the Fuller's Earth to the beds of Local Group 4 are here shown, thrown down by a fault, the angle of the upper beds approaching the perpendicular. In a small pit a search has apparently been made for the blue rock below the Fuller's Earth, since it is of considerable commercial importance as road-metal, on account of the binding qualities of the lime. The massive cherts and associated beds, however, alone occur; and, as it is some time since the pit was abandoned, the section is not so clean as might be wished, but on careful examination measurements can be obtained without much difficulty.

The calcareous series with the blue rock, exposed only 1300 feet farther north (a little west), as the crow flies, remains a mystery which I cannot explain. The beds here are the same as those exposed in the lane by Rabbitsheath Cottages, and unless the fault at the latter place has a much greater throw than appears, there is not room for the cherts to pass below the calcareous beds; again, the presence of Fuller's Earth at the top of the chert series in the Tilburstow Hill Fault pit and at the top of the calcareous series in the Plantation pit suggests a lithological change from south to north, although there is little room for that either. Yet some such change probably takes place; a 12-inch bed of limestone has been already referred to as overlying the cherts at this horizon (p. 116).

The following is the section in the Fault pit. Dip N., top of the section about 500 O.D.:—

Local Group 1.	Sandy Fuller's Earth, etc.	2 feet.
	Massive chert and interbedded layers of cherty sandstone	20 feet.
	Hard stone-beds of massive greensand, perhaps slightly cherty, particularly in the upper portion	15 feet.
	Hard beds, rather uncertain; no blue rock or other calcareous beds	10 feet.
	Cherty rubble sandstone-beds, as on Tilburstow Hill Common, etc.	10 feet.
	Coarse sand, strongly glauconitic	20 feet.
	Pebble sandy-bed, false-bedded, finely stratified; dark sandy matrix; usual Bargate pebbles	2 feet.
Local Group 4.	Coarse many-coloured sands; becoming red-brown, clayey, and finer low down; thickness not clear, as the bedding rapidly becomes normal, or uncertain from false-bedding; but at least	40 feet seen.

IV. Comparative Table of Sections of the Lower Greensand between Dorking and Blechingley, to show the Relations of the Different Beds along the Lower Greensand Ridge.

Notes on the Sections (see pp. 120, 121).

Fig. 1.—Compiled chiefly in Punchbowl Lane; the relative thickness of sands and clayey sands above the bed of chert is not clear. The thickness of the bed of chert is exaggerated in the figure.

Fig. 2.—Upper third of the section from Bell Street. The demarcation of the clayey sands from the sands above and below is not clear.

Fig. 3.—Upper half of the section from larger pits on Redhill Common. The junction of the Folkestone Sands and Fuller's Earth is not shown, and its nature cannot be otherwise ascertained.

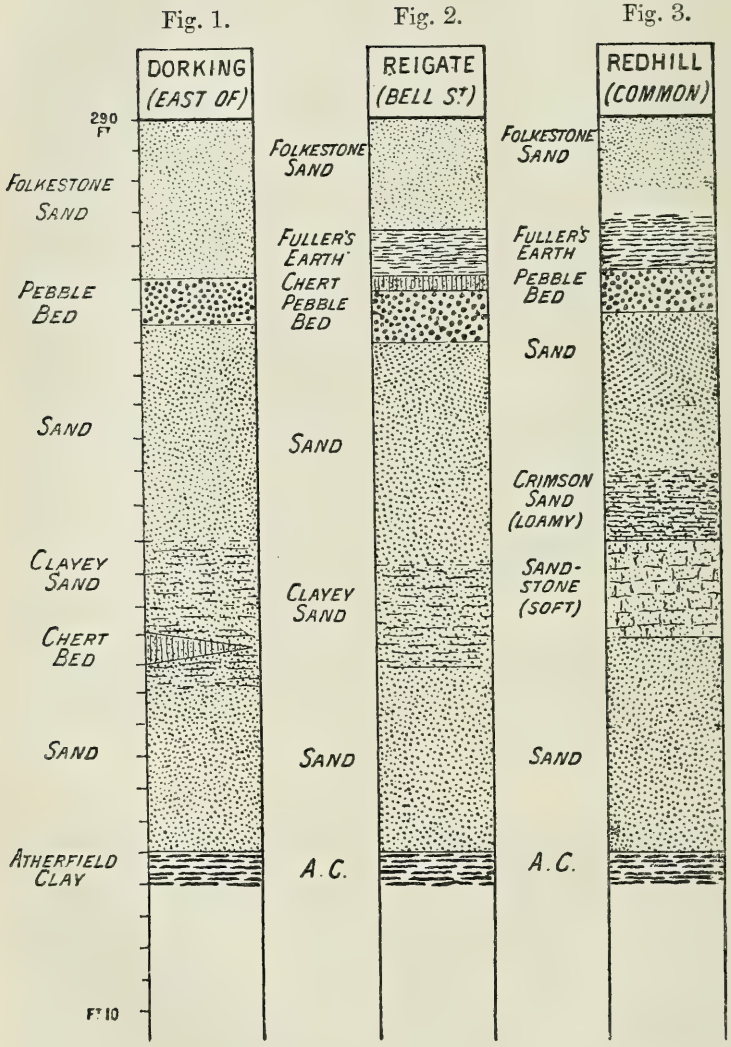
Fig. 4.—Upper two-thirds of the section from the Cockley and Park Fuller's Earth Works, and from the lane to Little Cormonger's Farm. The thin beds are slightly exaggerated, and the relative thicknesses of the sands and clayey sands are difficult to ascertain. This section shows the Lower Greensand to be somewhat thicker at Nutfield than east and west of that village. This may be a local phenomenon, or it may be due to an error in the determination of the position of the outcrop of the Atherfield Clay (mapped from surface-indications only) in consequence of undiscovered slips of sand; or again, it may be due to a change in the angle of dip in the lower beds (where the excess is here shown). When not shown in section, the thickness of all these beds has been calculated from outcrop to outcrop at the same dip as seen above or below, as the case may be. East of Nutfield a similar section can be compiled, from the Nutfield Chert-bed downwards.

Fig. 5.—No evidence above the topmost sandstone (1 foot). Upper fourth of the section from the lane east of the Castle, the remainder from surface-indications entirely.

Fig. 6.—Section from Outward Lane. The limestone is thicker here than to the east, and massive cherts now first appear in quantity. Upon this horizon the chert increases, and the sand associated with it decreases in quantity in passing westwards; these beds cap the Nutfield-Blechingley ridge almost constantly. The coarse sands are not sufficiently well shown to display the Pebble-bed here, but it probably occurs, as in the Fault pit at Tilburstow Hill, in a rudimentary condition. Limestone is first seen here on the probable horizon of the Kentish Rag, but it may have come in earlier, where these beds are mapped from surface-indications only.

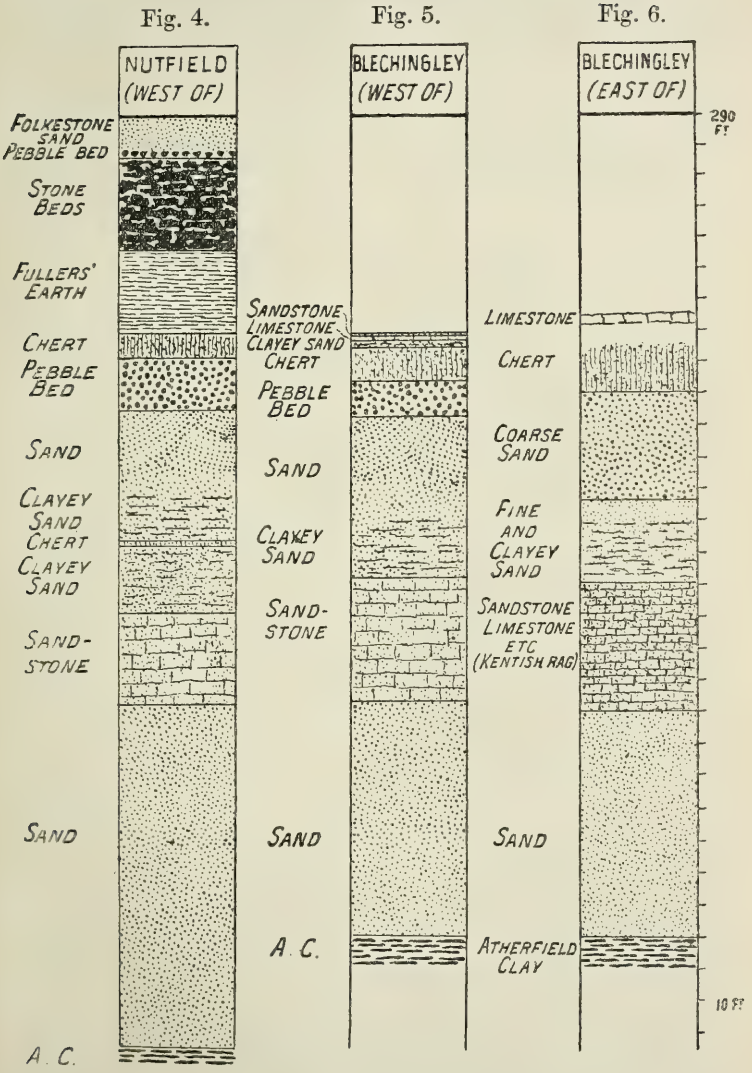
V. Conclusions.

The occurrence of fragments of the chert-beds over the surface of the Weald Clay S.S.E. of Dorking, and the presence of pebbles of chert in the alluvium and in the beds of the streams flowing from the same district (even to beyond the Lower Greensand escarpment, and yet east of the gap formed by the Mole in the Chalk at Dorking), clearly prove that at one time the Chert-beds existed east of where they are now seen *in situ*. But since the Lower Greensand area to the north of that district consists of sandy beds only, or at most contains only a thin bed of chert in the clayey sands, there must be a lithological change from south to north on this horizon [from less littoral to littoral conditions]. The quantity of Bargate débris in the drifts south and east of Dorking suggests further a thickening of these beds to the south also. In the Godalming-Guildford district Mr. Meyer, the officers of the Geological Survey, and Dr. Hinde



Vertical scale

Greensand between Dorking and Blechingley.



1 inch=60 feet.

have all shown that the Bargate Beds overlie chert-beds in the south, and sands in the north, a condition of things which agrees with what is now claimed to have formerly existed here. In the Leith Hill area the less littoral beds run up, as seen at Coast Hill, to the parallel of the sandy area, to the east and west; there is no difficulty in accounting for this when the conditions of a marine estuary are considered; it only shows that a 'deep' formerly existed there.

It is impossible now to more than glance at the most important of the many interesting points brought out by the table appended to this paper of sections from the country to the east. I have already pointed out that the Bargate Beds at Abinger are inseparable from the similar bed at the base of the Folkestones into which there is a complete passage there.[1] The Pebble-beds at the base of the Folkestones have been traced in this paper through the Dorking country to Reigate, where a thin bed of chert capped by thin Fuller's Earth alone separates them from the ironsands. The horizon of the two exposures of Pebble-beds above the top of the Atherfield Clay further approximates closely, east and west of the Mole Valley—160 to 170 feet at Punchbowl Lane and 160 at Reigate. The exposures of Pebble-beds at Reigate, Redhill, Nutfield, and Blechingley not only agree lithologically, but are in each section seen to be overlain by sandy cherts followed by Fuller's Earth. It is difficult to imagine what evidence could be required in such a set of beds to establish an horizon more perfectly. At Tilburstow Hill the Pebble-beds have almost thinned out; the pebbles generally decrease in size eastward. The overlying cherts, on the contrary, increase in importance to the east, on this horizon, until at Tilburstow Hill we find 55 feet of them.

Whatever may be the origin of the Fuller's Earth, it must certainly have been formed in quiet waters; but, as it overlies the less littoral beds of this country, the conditions for the formation of suitable lagoons can be easily imagined in a marine estuary such as is here described. The ironsands of Local Group 4 are seen everywhere at the base of the series where that horizon is exposed, and the so-called 'Hythe Beds' appear to die out within them east of this area. It is noticeable that, some way above the horizon of the probable Hythe Beds at Nutfield, a thin bed of chert occurs in clayey sands. It is almost too much to say that this is the representative of the Leith Hill horizon (Local Group 2), since, wherever conditions were favourable, sponges may have grown, but the horizon of its occurrence in clayey sands here exhibits a striking parallel to what occurs in Deepdene Park, near Dorking. The horizon of the Dorking clayey sands is suggested, to the east, by somewhat similar beds at many places, and these may mark the northern margin of the deeper water of that period. At Dorking the beds of Local Group 3 doubtless mark the margin of the still less littoral beds of the southern end of Leith Hill. The sandy limestones and associated beds above and between the Fuller's Earth

[1] Proc. Geol. Assoc. vol. xiii. (1893) p. 166; Quart. Journ. Geol. Soc. vol. l. (1894) p. 729.

at Nutfield, the possible lacustrine sands of Redhill, and the blue stone and associated calcareous beds of Tilburstow Hill Plantation are local formations which can be accounted for variously in the changing conditions of a marine estuary, but, considering their environment, not easily, I think, in any other way.

In conclusion, I would point out that the Folkestone Sands show deeper-water conditions at Folkestone, where Dr. Hinde has called attention to the sponge-beds,[1] whereas I have lately received from Mr. H. A. Maugles, F.G.S., a fossil fir-cone found by him during excavation in his grounds at Littleworth Cross, Tongham, in West Surrey, on the same horizon. These two observations, taken together, show clearly in which direction the land lay at that period.

Discussion.

Mr. C. J. A. Meïer thought the paper a difficult one to discuss, because the Author had discarded the usual subdivisions of the Lower Greensand. He did not see why deep-sea conditions should be supposed to have prevailed during the deposition of the chert-beds of Leith Hill, and shallow-water conditions at the same time only 5 miles to the north. He thought it probable that the development of chert in sand-beds depended partly on the partial exposure of the sand to atmospheric conditions, and that the almost total absence of chert near the escarpment of the North Downs was due in part to the non-exposure of the sand-beds.

Dr. G. J. Hinde agreed with the Author as to the important development of the beds of sponge-rock in the Lower Greensand of this district. They varied very much in their characters, from a few loose spicules scattered through the sand to beds of solid chert nearly wholly composed of these small bodies. He thought, however, that the Author was in error in considering the chert-beds or sponge-rock in the Greensand as deep-water deposits, for both the nature of the sponge-remains and the associated sandy sediments clearly indicated that they were not formed in deep water. The cherty sponge-rock was of a very resistant character, and fragments of it were widely distributed in areas where the sandy beds had disappeared.

Dr. J. W. Gregory said that he felt much interest in this paper, as he had examined a good deal of the country in the effort to make a map of the coast-line and shore-deposits of the Lower Greensand sea. He worked over the Reigate-to-Tilburstow area in the winters of 1887–88 and 1888–89, but had left this, as, though the sections were clear, the mapping was more difficult than farther west. He had expressed views generally similar to those of the Author at an excursion of the Geologists' Association (Proc. Geol. Assoc. vol. xiii. pp. 377–381), but differed in some details. Thus he doubted the value of the pebble-beds as a constant horizon: for example, a section at Betchworth, intermediate between two of those described by the Author, showed more than one pebble-bed. He thought that promontories projected from the coast, while on the two sides different deposits were piled up, and these were not capable

[1] Phil. Trans. Roy. Soc. vol. clxxvi. (1885) p. 410.

of precise correlation. Further, he thought that the currents ran not from N.W. to S.E., but in the opposite direction, and that to the west was a connexion with the sea north of the land-area then in existence. The discovery of a Gault species of *Pinites* was of interest, as it seemed probable that much of the 'Folkestone Sands' was of Lower Gault age. He doubted the necessity for the new names, and thought it best to restrict the term 'Bargate' to the limestones to which it was given, and not to apply it to beds of different composition in which the Bargate fauna does not occur. In his remarks to the Geologists' Association he had not referred to the cherts still *in situ* as deep-sea beds, but to others now known only by fragments in the High-level and Southern Drifts.

Mr. Boulger remarked that, as a native of the district under discussion and as having had the pleasure of being to a small extent associated with the Author in his work on part of the district, he was naturally much interested in the paper. The Fuller's Earth was distinctly traceable in the eastern end of the area, *i.e.* in Blechingley, throwing out springs on the slope from the escarpment northward. It might be topographically useful to record that the so-called 'Reigate Stone,' much used for building in the neighbourhood, had been largely quarried from the 'Stone-beds' in the pit behind the parochial school at Nutfield; and that Red Hill was an abbreviation of Redstone Hill, the name of the hill east of the railway, where the red beds were present as well as on the Common. He thought that, with the exception of the Atherfield Clay, the subdivisions could not be mapped, for want of satisfactory base-lines.

The Author, in reply to Mr. Meÿer, said that the Lower Greensand was known to thin out under London. As to the use of local names to describe the different beds, it was stated in the paper that this was solely for the purpose of clear exposition here, since the subject had become so terribly confused through different authors using different terms for the definition of the same beds; one instance was noted in the paper, where the same bed had been ascribed by three authors respectively to the three divisions of the Lower Greensand. He had retained the term 'Folkestone Beds,' although one speaker had objected to that also, because there was no serious confusion as to this horizon. He did not profess to have minutely searched the whole of the sandy area to the south of Dorking for sponge-spicules: there was over 100 feet of sands exposed; he had examined a large number of samples, however, and did not think that spicules occurred there. The term 'deep-water beds' was his own, but the specimens on the table showed that the true sponge-beds occurred plentifully at the southern end of Leith Hill. He should have mentioned that he made a distinction between these true sponge-beds and the cherts, which were extremely sandy and were typical of the northern end of the hill. The thickness given to the cherts was obtained by the levels of the outcrops at the southern end of the hill. He was sorry that there was no time to refer to the other criticisms, but he had, he thought, replied to the more serious ones. The paper was one which could not and should not escape criticism.

15. CARROCK FELL: *a* STUDY *in the* VARIATION *of* IGNEOUS ROCK-MASSES.—PART II. THE CARROCK FELL GRANOPHYRE. PART III. THE GRAINSGILL GREISEN. By ALFRED HARKER, Esq., M.A., F.G.S., Fellow of St. John's College, Cambridge. (Read January 23rd, 1895.)

[PLATE IV.—MAP.]

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PART II. THE CARROCK FELL GRANOPHYRE.

9. INTRODUCTION.

IN a former paper I have given a general sketch of the geology of the Carrock Fell district, and discussed the remarkable variations observed in the gabbro which is there exposed.[1] The present communication deals with the granophyre, which is closely associated with that gabbro, and with another interesting acid rock, not far distant, but belonging to a different group of intrusions.

The granophyre occurs in several distinct masses, which, from their general eye-shaped outcrop and parallelism of strike with the adjacent rocks, must be regarded as laccolitic intrusions (see sketch-map, Pl. IV.). The similarity of these neighbouring masses justifies us in considering them as a connected group. The one most easily studied is that which builds Carrock Fell itself, and extends westward in a tongue nearly as far as Round Knott. The exposures

[1] Quart. Journ. Geol. Soc. vol. l. (1894) pp. 311–335. I take this opportunity of adding a supplementary note to that paper. In describing the mineralogical constitution of the gabbro, I spoke with some caution of the occurrence of a subordinate rhombic pyroxene, inferred from the presence of certain pseudomorphs in the rock. A subsequent study of a series of slides, kindly placed at my disposal by my friend Mr. T. T. Groom, enables me to confirm this identification. One of these specimens, collected at the base of the cliff, is an unusually fresh example of the gabbro, and this contains a rhombic pyroxene in considerable abundance. Its relatively weak double refraction, pale colour, and absence of any sensible pleochroism place it under enstatite rather than hypersthene. It builds roughly idiomorphic prisms, and is often in parallel intergrowth with augite. In this case the latter mineral commonly borders the crystal, but little patches of augite are sometimes intimately associated with the enstatite with a rude micrographic arrangement. The enstatite is usually quite fresh in this slide, but in places it passes over into a greenish fibrous hornblende or actinolite [2279].

about Rae Crags, farther north-west, probably belong to a mass distinct from the preceding, separated from it by diabase, and faulted on the north against the Eycott Hill lavas and the Drygill Shales. Granophyre is seen at certain points on the moorland of which Great Lingy is the centre: if these outcrops belong to one connected mass, its extent from Roughten Gill eastward must be nearly 2 miles. There are smaller intrusions in Arm o' Grain and other gills, but we may confine our attention chiefly to the mass first indicated, which is well exposed about Carrock Fell and the Pike and in the cliffs known as the Scurth.

The question of the geological age of the granophyre and the slightly earlier gabbro is one bound up with the interpretation of the general structure of the Lake District, and must be very briefly dismissed in this place. The rocks have been intruded at the junction of the Skiddaw Slates and the Eycott Hill lavas since these two groups assumed their present mutual relations. There is reason to believe that these relations are not the natural ones, and that the absence here of certain other groups which should intervene is a result of the great post-Silurian crust-movements. If this be so, the intrusions must be later than these crust-movements. The absence of cataclastic structures or any phenomena attributable to shearing in the intrusive masses is, so far as it goes, a confirmation of this view. The faults which have displaced the intrusive rocks are to be referred to the later (post-Carboniferous) system of disturbances, with which the metalliferous lodes of the region in general seem to be connected.

10. Description of the Granophyre.

Before considering the variation exhibited by the Carrock Fell granophyre, a short description must be given of what we may regard as the normal type of the rock. It is essentially an augite-granophyre, the mineral named being always present and being the only ferro-magnesian constituent of the rock.

The only common accessory mineral is zircon, which is very generally distributed in small prisms with square cross-section. A little original magnetite occurs in a few slides, but is never prominent.

The augite of this rock presents a strong contrast to that of the gabbro. It builds crystals sometimes showing a good octagonal cross-section, more usually rather rounded and irregular, but always idiomorphic towards the felspar. The fresh crystals are of a pale to deep green tint in slices, but the mineral is commonly more or less completely replaced by a green decomposition-product of chloritic or perhaps serpentinous nature. This is strongly pleochroic, the absorption-colours changing from bluish-green to greenish-yellow: its birefringence seems to vary considerably. Uralitization is also observed in many of the slides.

The frequent association of augite with granophyric structures in our British rocks is a point worthy of passing notice. It is observed

alike in the Ordovician intrusions of North Wales and in those of Tertiary age in Scotland. In Caernarvonshire the facts are specially striking.[1] There the typical granophyres always carry augite, to the exclusion of biotite; the ruder types of granophyre and the granite-porphyries contain the two minerals together; and the true granites have biotite alone. Analyses of the Charnwood Forest rocks seem to prove that augite and micropegmatite can be formed together from magmas possessing a wide range of chemical composition.[2]

Another remark may be made on the augite of the Carrock Fell granophyres. As a rule, the length of a crystal is at most twice or thrice its breadth. In the upper part of Clints Gill, however, the most easterly tributary of Roughten Gill, the augite assumes an elongated needle-like habit. The same thing is seen east of Rae Crags, where the needles are from 1 to $1\frac{1}{2}$ inch in length and less than $\frac{1}{20}$ inch in diameter. Here, too, the idiomorphic felspar takes on a similar acicular habit. These localities are near the boundary of the granophyre, and it is interesting to compare the phenomenon with the narrow blade-like habit of the biotite in other acid intrusions in the Lake District. Mr. Marr and I have noted this feature in connexion with marginal modifications of the Shap granite [3] and the Dufton granite-porphyry.[4] It is found also in the quartz-porphyries of Potter Fell and Wansfell, and at the border of the Buttermere granophyre near Strands. The point is of interest in the present instance of the Carrock Fell granophyre; for, if the peculiar habit of the augite can be safely regarded as part of a marginal modification of the rock, it proves that the mineral crystallized after the intrusion of the magma, and indeed—since there is no parallel arrangement of the needles—after the cessation of flowing movement.

The felspars of the granophyre include scattered idiomorphic crystals and the much more abundant felspathic constituent of the micropegmatite. The former give sharply bounded rectangular sections with albite- and pericline-lamellation, and sometimes Carlsbad twinning in addition. The low extinction-angles of the lamellæ indicate oligoclase, but a frequent zonary banding, seen between crossed nicols, shows that the crystals are not quite homogeneous.

The chief bulk of the rock consists of felspar and quartz showing a great variety of 'granophyric' structures. Under this inappropriate term 'granophyric' Rosenbusch has included both evident micrographic intergrowths of felspar and quartz (micropegmatite), analogous on a small scale to 'graphic granite' (the original pegmatite of Haüy), and the various types of spherulitic and 'pseudo-spherulitic' structure. Recent researches have rendered it highly probable that the latter are merely very minute—and perhaps sometimes ultra-microscopic—groupings of felspar-fibres and intergrowths

[1] See 'The Bala Volcanic Series of Caernarvonshire,' Cambridge, 1889, § iv.
[2] Berry, Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 197.
[3] *Ibid.* vol. xlvii. (1891) pp. 277, 284.
[4] *Ibid.* p. 520.

of felspar and quartz, not essentially different from the centric type of micropegmatite. Indeed, the evidence put forward by Whitman Cross[1] and Iddings[2] amounts almost to demonstration. The Carrock Fell rock exhibits, better than any other with which I am acquainted, the various stages of gradation from a coarse and irregular micropegmatite to spherulitic intergrowths of a delicacy surpassing the resolving power of the microscope. These structures collectively will be conveniently designated 'graphic' structures. The name 'granophyre' applied to rocks of this type is perhaps too well established by usage to be abandoned.

When the intergrowth is on a relatively coarse scale, it is usually rude and irregular. Indeed, some specimens of the rock show little or no graphic structure at all, the felspar and quartz forming an irregular mosaic. In this case the quartz tends to occur partly in larger crystal-grains, and the rock approximates to some quartz-porphyries. This, however, is exceptional, almost all the slides examined showing at least a partial micrographic structure. The more finely-textured micrographic intergrowth always shows a regular arrangement. Sometimes the arrangement is linear or parallel; more frequently it is centric; but in all cases a large part of it stands in definite relation to the porphyritic crystals of oligoclase, forming a more or less regular frame round each crystal. In very many cases it can be verified that part of the felspar of the intergrowth is in crystalline continuity with the felspar-crystal which has served as the nucleus for its growth. The appearance is as if the original crystal had continued to grow throughout the final stage of consolidation of the magma, enclosing the residual excess of silica as intergrown quartz. In some instances a line of Carlsbad twinning can be traced from an oligoclase-crystal through the enveloping framework. It is clear that much of the felspar in the micrographic intergrowth must be of a plagioclase variety. In some Caernarvonshire granophyres I have found that the felspar of the micrographic intergrowth is in continuity, not with the plagioclase-crystal which forms the nucleus, but with an extremely narrow border of orthoclase investing the plagioclase.[3] In the Carrock Fell rock I have not observed this peculiarity, though it is seen in some specimens from Buttermere.

The more delicate the micrographic intergrowth, the more marked is the tendency to a 'centric' or radiate arrangement, with or without a nucleus of an earlier crystal. With increasing fineness also the sectors within which the felspar of the intergrowth extinguishes simultaneously become narrower, until they are represented between crossed nicols merely by dark rays when their direction makes a small angle with one of the cross-wires. The felspar of the intergrowth takes on more markedly the form of radiating fibres, and seems to make up a larger proportion of the whole. This latter appearance is perhaps illusory, but it is certain that the aspect of

[1] Bull. Phil. Soc. Washington, vol. xi. (1891) pp. 411–444.
[2] *Ibid.* pp. 445–464.
[3] 'The Bala Volcanic Series of Caernarvonshire,' 1889, p. 48.

these radiate aggregates is determined chiefly by the minute radially-grouped fibres of felspar which obscure the associated quartz.

From the micrographic the transition is unbroken to what may be called the 'cryptographic' structure, in which the individual elements of the intergrowth are no longer to be distinguished, Here presumably the constituent sectors are still more attenuated, and the radial arrangement of the fibres is in consequence more perfect. A black cross is seen between crossed nicols, though, owing to the slightly oblique extinction of the felspar which is the dominant mineral-element, the arms of the cross are not very perfect nor accurately at right angles. The structure is thus the pseudo-spherulitic rather than the truly spherulitic of Rosenbusch, but from our point of view the distinction is not essential.

Graphic intergrowths are not always restricted in this rock to the quartz and felspars: exceptionally they affect the other constituents also. Certain slides show a radiate grouping of the minerals on rather a large scale (relatively to the field of the microscope), imperfect prisms of felspar being arranged like the spokes of a wheel. In this case the green augite occurs in irregular rod-like and elongated patches sharing the general radiate disposition [2280]. Again, there are not wanting indications of a micrographic intergrowth on a small scale between augite and the other constituents, including magnetite, though the decomposition of the augite renders the appearance rather obscure. So far as I have observed, this structure is found only in the remarkable basic modification of the granophyre near its junction with the gabbro.

The following analysis of the Carrock Fell rock is due to my friend Mr. George Barrow, F.G.S., of the Geological Survey of Scotland. It may be taken as representing the composition of an average specimen; the specific gravity was found to be 2·670 :—

	III.
SiO_2	71·60
Al_2O_3	13·60
Fe_2O_3	2·40
MgO	0·21
CaO	2·30
Na_2O	5·55
K_2O	3·53
Loss on ignition	0·70
	99·89

III. Granophyre, 100 yards east of summit, Carrock Fell. The iron is estimated as ferric oxide, but doubtless occurs mostly in the lower form: the figure given corresponds to 2·16 of ferrous oxide.

The analysis by Mr. J. Hughes given in Mr. Ward's paper[1] shows a general agreement with the above, except as regards the soda, which must be largely overestimated.[2]

[1] Quart. Journ. Geol. Soc. vol. xxxii. (1876) p. 24.

[2] It is evident that, when the only alkali-bearing minerals are felspars, the molecular ratio $K_2O+Na_2O : Al_2O_3$ in the bulk-analysis of a rock cannot be greater than unity, and must be less if a lime-bearing felspar or an aluminous pyroxene be present. The ratio calculated from Hughes's figures is 1·7 : 1.

From Mr. Barrow's analysis, in conjunction with the microscopical examination, the mineralogical composition of the granophyre may be calculated as follows:—

	Plagioclase.	Orthoclase.	Quartz.	Augite.	Totals.
SiO_2	32·90	13·50	20·96	4·24	71·60
Al_2O_3	9·75	3·84	...	...	13·59
FeO	...	...	...	2·15	2·15
MgO	...	...	...	0·21	0·21
CaO	0·33	...	...	1·97	2·30
Na_2O	5·55	...	...	...	5·55
K_2O	...	3·53	...	...	3·53
	48·53	20·87	20·96	8·57	98·93

From this it would appear that the plagioclase-felspar of the rock is one of the albite-oligoclase series with a ratio Ab : An = 7·4 : 1, or nearly 15 : 2, its percentage composition being as below. This, however, is only the average composition, and it may well be that the porphyritic crystals are of a more typical oligoclase, while the triclinic felspar which, with the orthoclase, makes the felspathic constituent of the micrographic groundmass is a more nearly pure albite.

Plagioclase.		Augite.	
SiO_2	67·79	SiO_2	49·47
Al_2O_3	20·09	FeO	25·09
CaO	0·68	MgO	2·45
Na_2O	11·44	CaO	22·99
	100·00		100·00

The augite would appear to be a diopside approaching hedenbergite, the ratio Mg : Fe being 21 : 215, or nearly 1 : 10 ; but the calculation is probably of little value in view of the small part which the mineral plays in the rock. It is evident, however, that the augite cannot be of a variety rich in alumina, and this makes another point of contrast with the augite of the gabbro.

11. Variation observed in the Granophyre.

Over a large part of its extent the granophyre of the Carrock Fell intrusion does not seem to vary much from the specimen analysed, and the same is true of the intrusions of Rae Crags and Great Lingy. The highest percentage of silica found was 77·38, at a spot below the Scurth, about 500 yards W.N.W. of Stone Ends farm.[1] On the other hand, portions of the Carrock Fell mass are

[1] The following silica-percentages of different specimens of granophyre I owe to the gentlemen named in my former paper. Those marked S were determined at Sidney Sussex College by Messrs. Brend and Cunningham-Craig, those marked L were determined at Leeds by the pupils of Dr. Cohen :—

(i) Below Scurth, at 500 yards W.N.W. of Stone Ends:
Silica 77·38 (S) ; sp. gr. 2·607.
(ii) In peat-moss S. of Drygill Head: Silica 75·3 (L) ; sp. gr. 2·530.
(iii) Outcrops 100 yards E. of Carrock Fell summit:
Silica 71·60 (Barrow) ; sp. gr. 2·670.

considerably less acid than what has been described as the normal type. The specific gravity increases from 2·7 to 2·8 and even to 2·9 or more. This is at the southern margin of the intrusion, where the silica-percentage of the granophyre, in contact with the gabbro, has fallen to less than 60. The microscope shows that concurrently the rock becomes richer in augite, and in its most basic phase contains a notable proportion of iron ores and apatite, with sometimes a little biotite.

These variations are sufficiently apparent in hand-specimens taken in the field. The normal type of granophyre shows small scattered crystals of black augite and white or glassy-looking oligoclase, in a fine-textured grey, or cream-coloured, or reddish groundmass. In some of the more acid examples the augite is wholly or almost wholly absent, and the rock has a white colour. This is the case at the head of Brandy Gill and in the peat-moss south of Drygill Head, and the specific gravity of these specimens is naturally very low (2·578 and 2·530). In other places the granophyre becomes richer in augite, the lustrous columnar crystals of that mineral and the duller black spots which mark its decomposition-products, together with the white crystals of felspar, being more closely set in the reddish or brownish granophyric matrix. This variety prevails especially towards the southern boundary of the Carrock Fell intrusion. The augite is not only more abundant, but in larger crystals, and indeed the whole rock assumes a coarser aspect in this part of the mass. On the actual margin these peculiarities are more marked, and are worthy of more detailed notice.

Before describing the special phenomena at the junction of the granophyre with the gabbro, however, it will be convenient to enquire whether the facts already broadly stated lead to any plausible explanation of the variation observed in the different parts of the acid intrusion. The occurrence of the densest and most basic type of granophyre on the southern edge of the mass, which seems to represent its base as originally intruded,[1] suggests at once the differentiating action of gravity. There are two ways in which this might conceivably take effect: namely, by a stratified arrangement of layers of different density in a magma still wholly fluid, or by the sinking of crystals already separated out in the magma.

The former hypothesis, which is as old as Durocher's famous theory, has been made the basis of speculations by several writers, and I have endeavoured to develop it in connexion with the suc-

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(iv) Carrock Fell summit: Silica 69·044 (Hughes, *cit.* Ward); sp. gr. of specimen from same locality, 2·657.

(v) Close to junction with gabbro, lower part of Furthergill Sike: Silica 60·0 (L); sp. gr. 2·805.

(vi) Another specimen from the same place: Silica 58·26 (S).

I have made specific-gravity determinations on specimens from twenty other localities, and found them a useful check upon the examination of hand-specimens and slices. The figures are all corrected to the standard temperature, 4° C.

[1] See my former paper, Quart. Journ. Geol. Soc. vol. l. (1894), section on p. 314.

cession of the Ordovician lavas and the associated intrusive rocks in Caernarvonshire.[1] It may have an application also to a system of sills or laccolites of cognate origin, such as those belonging to the earlier (probably Ordovician) system of intrusions in the Lake District.[2] In such cases we are dealing with differences of level of many thousands of feet, and it is doubtful whether differentiation of this kind could produce appreciable effects within the limits of a single body of eruptive rock such as can be exposed for our examination. Even if the parallel between a rock-magma and a saline solution be granted, physical researches on solutions do not give us any quantitative results available for our purpose. In simple solutions Gouy and Chapéron[3] have calculated that the concentration by gravity would become sensible only in a vertical column at least 100 metres in height. On the whole, we cannot at present look to this process as likely to have been an important cause of differentiation in a laccolite of moderate dimensions, such as the Carrock Fell granophyre. Moreover, there are facts for which it offers no explanation.

The idea of minerals separated out in the early stages of crystallization sinking to the bottom of an otherwise fluid magma is also one that has been entertained by other writers, and I have elsewhere applied it to some of the later (post-Silurian) intrusions on the border of the Lake District.[4] It does not seem, however, to afford an explanation of the facts in the present case. In the intrusion of Carrock Fell itself the basic modification of the granophyre is certainly found along the southern, *i. e.* the lower, boundary; but if we consider the other granophyre-intrusions in the neighbourhood, already enumerated, we see that no such rule holds good. We cannot then ascribe the richness in augite, iron

[1] 'The Bala Volcanic Series of Caernarvonshire,' Cambridge, 1889, § viii.

[2] The following are arranged in descending order:—

(i) Sill of quartz-porphyry between Ashgill Shales and Coniston Limestone, Far Old Park, Dalton-in-Furness; sp. gr. 2·574.

(ii) Sill of microgranite in Coniston Limestone, Taith's Gill Bridge, near Sedbergh; sp. gr. 2·590.

(iii) Sill of quartz-porphyry in banded ashes near Long Crag, Wrynose Gill; sp. gr. 2·597.

(iv) Sill below banded ash-group on west flank of Helvellyn; sp. gr. 2·726.

(v) Irregular sill of dolerite near junction of Volcanic Series with Skiddaw Slates, Lyulph's Tower, Ullswater; sp. gr. 2·803.

(vi) Irregular sill or laccolite of hornblende-picrite (of Mr. Postlethwaite) in Skiddaw Slates, Great Cockup; sp. gr. 2·923.

There seems to be no exception in the Lake District to the rule that the lower sills are of denser rocks than the higher. The figures stated are, of course, for the solid rocks, but it is safe to assume that those for the fluid magmas would give the same relative order.

The vertical range here represented must be very considerable; Mr. Clifton Ward estimated the thickness of the Volcanic Series alone at 12,000 feet.

[3] 'Sur la Concentration des Dissolutions par la Pesanteur,' Ann. Chim. et Phys. ser. 6, vol. xii. (1887) pp. 384–393. Actual experiments on this point by Bischof and others have not yielded any consistent results.

[4] 'The Lamprophyres of the North of England,' Geol. Mag. 1892, pp. 199–206; 'Porphyritic Quartz in Basic Igneous Rocks,' *ibid.* pp. 485–488.

ores, and apatite of certain parts of the granophyre to the effect of gravity, whether operating on the fluid magma or on minerals crystallized out at an early stage.

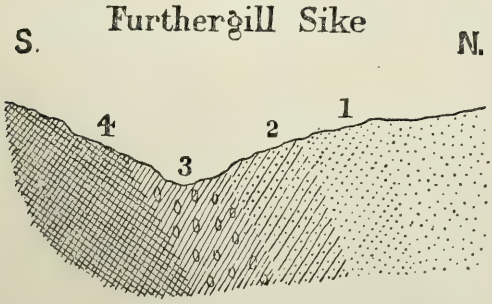
As already remarked, the tracts occupied by granophyre are often covered by peat-mosses and other superficial accumulations, and the precise limits of the intrusions are in some places a matter of conjecture; but all that can be observed favours the view that the basic modification of the rock is a marginal phenomenon, and comes in near the contact of the granophyre with the gabbro. The gabbro-intrusion we know to be of somewhat earlier date than that of the acid rock, but it is highly probable that the interval between the two was a short one, so that the acid magma was intruded among rocks already hot. We should not, therefore, look for a marginal concentration of the earlier products of crystallization in the granophyre, such as we have found evidence of in the gabbro; and the phenomena here considered must be different in kind from those discussed in my former paper. In proof of this it must be remarked that the basic margin to the granophyre is found (so far as our knowledge goes) only where that rock is in contact with the gabbro. For example, the granophyre about Rae Crags and to the south, which is in contact with the later intrusion of diabase, is of a thoroughly acid type (specific gravity 2·647).

These considerations suggest that the curious modification of the Carrock Fell granophyre on its southern border is due to a reaction between the acid magma and the highly basic margin of the previously consolidated but still hot gabbro. It will be seen that this idea is confirmed by a closer examination of the rocks in question.

12. Junction of the Granophyre with the Gabbro.

The junction of the granophyre with the gabbro is best observed in Furthergill. The following section is seen in a distance of 3 or 4 yards from north to south, low down in the little sike, just before

Fig. 1.



the outcrops are lost under the alluvial fan. No. 1 is granophyre of specific gravity 2·705, and doubtless of considerably less acid

composition than the normal type. From this it differs mineralogically, chiefly in the greater abundance of augite which it contains. That mineral builds the usual idiomorphic crystals, but is largely replaced by green hornblende and other substances. We also note the presence of iron ores, which were mentioned as rare, and apatite, which was almost wholly wanting, in the normal type. The idiomorphic zoned felspar-crystals are abundant, and the interstitial micropegmatite occupies somewhat less space than formerly. No. 2 has a specific gravity of 2·805, with a silica-percentage of only 58 or 60. The augite, in rather large idiomorphic crystals, is somewhat more abundant, and the apatite and iron ores are also more prominent constituents. In addition a little biotite is found. Besides the beautiful micropegmatite which clings about the idiomorphic felspars, there is in places what looks like a kind of micrographic arrangement in the destroyed augite and even in the iron ores. The same thing is seen in No. 3, a still more basic rock, of specific gravity 2·925. The augite and its alteration-products are perhaps a little more plentiful, and the same may be said of the iron ores, the apatite-prisms, and the scanty flakes of biotite. The idiomorphic felspars are often seemingly untwinned, but their zonary banding is still marked. The micropegmatite is reduced in quantity, and tends to consist mainly of quartz. On the other hand, there are micrographic intergrowths of felspar and (destroyed) augite. This rock has a very compact, dark aspect in the field, and weathers into spheroids. It seems to represent the actual border of the granophyre-intrusion, for it is in contact with undoubted gabbro, though of somewhat peculiar character. Some brecciation indicates a certain amount of crushing along the line of junction, but there is evidently no break of importance. The gabbro, No. 4, is the extreme basic modification of that rock, its specific gravity being 3·200 and its silica-percentage only 33·4. It exhibits the peculiar metamorphic effects noted in my former paper, such as the abundant production of tremolite, sphene, etc., with the destruction of the original minerals; but enough remains of the latter to mark the fundamental difference between this rock and the preceding. For instance, the augite of the gabbro is of the pale greyish-brown variety with characteristic basal striation, and always moulds the felspar-crystals.

In this section we see that, notwithstanding the curious basic modification of the granophyre towards its southern margin, the line of separation between that rock and the gabbro can be drawn with absolute sharpness. The fact that the gabbro becomes progressively more basic towards its northern boundary has already shown us that there is no passage from the one rock to the other in the usual understanding of the words; we now see that neither chemically nor mineralogically is there a gradual transition from the one intrusion to the other. The silica-percentage of the granophyre, for instance, decreases gradually down to about 58, but then the figure drops *abruptly* to $33\frac{1}{2}$ in the ultrabasic gabbro. Again, the granophyre becomes continually richer in augite as we approach

the Furthergill stream, yet there gives place to a rock containing abundant augite indeed, but of a quite different variety, namely, the aluminous ophitic augite with basal lamellation which we have found to characterize the gabbro-mass throughout its extent.

Following the line of junction up Furthergill Sike and westward towards Round Knott, we do not always find quite identical relations. Though the abrupt break is not bridged over, there are places where the difference in silica-percentage between the two rocks in contact one with the other would probably be less than that just noted. This is where there has been a certain impregnation of the marginal gabbro by granophyre.[1] So far as my observation goes, this is exceptional, and does not extend more than a couple of feet from the actual junction. The anomalous character of these quartz-bearing ultrabasic rocks is very striking. One, with a specific gravity of 3·026 to 3·122, is seen in the prominent crag overlooking Furthergill Sike at the spot marked by the letter F on the 6-inch Ordnance map.

In some places, too, the relations are complicated by apophyses of the granophyre traversing the gabbro. This complication is brought out by a longer traverse across Furthergill Sike, a little above the crag just mentioned. It is not necessary to give full details of this section. The basic modification of the granophyre (α, sp. gr. 2·724) is in contact with the highly basic iron-ore-gabbros (β, sp. gr. 3·060, and δ, sp. gr. 3·190), but the latter are divided by a tongue of thoroughly acid rock (γ, sp. gr. 2·636).

On the fell above there are only occasional exposures along the line of junction. About 100 yards south of the Carrock Fell sheepfold is seen a very coarse rock containing columnar black crystals up to 2 inches in length. These are, in the main, of hornblende, but it is not clear to what extent that mineral is derivative from augite. Certainly in some cases, in this and other specimens, hornblende occurs with its own proper crystal-forms. Biotite, iron ores, and apatite are also seen in a hand-specimen, while the microscope shows a micrographic groundmass clinging round the large idiomorphic felspars. Augite occurs also both in idiomorphic crystals, with partial uralitization, and in micrographic intergrowth. This rock, with a specific gravity of 2·738, is not unlike No. 2 of the above section, though perhaps a little more acid.

About 300 yards west of the summit of Carrock Fell occurs another coarse-textured rock which, on a large scale, shows a curious mottling of pink felspathic and black pyroxenic patches. The idiomorphic felspars here tend to narrow elongated forms. Biotite is present, as well as the abundant augite and hornblende. This rock has a specific gravity of 2·904, and corresponds to No. 3 of the section noted above. This and the preceding evidently belong to the basic margin of the granophyre. The dark ultrabasic gabbro, metamorphosed and partially impregnated with granophyre, is seen in loose blocks, but does not make any show *in situ*. This is

[1] See my former paper, Quart. Journ. Geol. Soc. vol. l. (1894) pl. xvii. fig. 6.

explained by its tendency to weathering; as seen in Furthergill it is usually very rotten. Dark brown mica, magnetite, and needles of apatite are conspicuous among the partly decomposed augite, hornblende, etc., of the crumbling rock.

All these facts are consistent with, and seem to lead to, the conclusion that portions of the highly basic gabbro have become incorporated with the acid magma near the junction of the two intrusions. The manner in which the actual margin of the gabbro as now seen is locally impregnated with granophyre proves that such an absorption of gabbro-material into the acid magma must have taken place to some extent, the mode of occurrence of the veins and nests of micropegmatite in the iron-ore-gabbro pointing clearly to corrosive action rather than merely mechanical disruption. The absorption in this way of some constituents of the gabbro must, on the edge of the solid mass, have disengaged crystals of other constituents, to be floated off in the acid magma and, whether fused or not, to modify the composition of the resulting rock. If we may suppose such an action to have taken place to any considerable extent, the peculiarities observed in the marginal part of the granophyre find a sufficiently simple explanation. That considerable portions have been removed from some parts of the gabbro-margin we have seen independent reasons for believing. (See p. 331 of my former paper, Quart. Journ. Geol. Soc. vol. l. 1894, and the accompanying map, pl. xvi.)

If such a reaction as that postulated on the above grounds, between the already consolidated basic gabbro and the acid magma, be admitted as a possibility, it may throw some light on the nature of the process to enquire what has become of the several constituents of the destroyed gabbro. The order of formation of minerals from a rock-magma does not in general correspond exactly with the (reversed) order of fusibility of those minerals, and many geologists have preferred the analogy of the crystallization of a mixture of salts from solution. Conversely, the absorption of crystallized minerals by a fluid magma may be compared with solution or chemical corrosion rather than with dry fusion. Since, however, the order of consolidation of the constituents of our gabbro is the same as their (reversed) order of fusibility, this question need not be discussed. The augite of the gabbro, then, would be the mineral most readily attacked, and it seems to have been wholly dissolved and its substance incorporated in the granophyre-magma; no augite resembling it is found in the basic margin of the granophyre-intrusion. From its interstitial mode of occurrence in the gabbro it is clear that the removal of the augite from the marginal part of that rock would set free the crystals of the other constituents. The felspar seems also to have been dissolved in great part, though it is possible that some of the relatively large crystals of plagioclase seen in the modified granophyre have been directly derived from the older rock. These crystals are much more plentiful here than in the normal

granophyre, and they frequently show a clear border surrounding a turbid nucleus of rounded shape and corroded appearance. Of such a derived origin there seems to be clearer indication in the case of the less fusible minerals, the iron ores and apatite. The shape of some of the larger opaque grains in such rocks as Nos. 2 and 3, described above, is significant. Especially may be remarked skeletons or frameworks, apparently of ilmenite, which perhaps represent the intergrowths of ilmenite and magnetite in the gabbro from which the latter mineral has been dissolved out. The apatite-crystals in the basic modification of the granophyre exactly resemble those in the gabbro, and are probably derived, without alteration, from that source. It will be remembered that this mineral is foreign to the normal granophyre.

The 'caustic' action of a fluid magma upon solid rocks has been studied by many geologists in connexion with the phenomena of enclosed fragments, and an excellent summary of knowledge on this point has recently been given by Zirkel.[1] From this it appears that in extreme cases an enclosed fragment of an igneous rock may be completely dissolved, with the exception of a few refractory minerals such as zircon, sapphire, etc. The corrosive action is most intense when the rock attacked and the absorbing magma differ widely in acidity; and we thus see why the action of the granophyre-magma upon the highly basic gabbro was much more energetic than that of the gabbro-magma upon the enclosed masses of basic lava (compare my former paper). A high temperature is another factor involved; and probably the peculiarity of the conditions in the present case lay in the intrusion of a considerable body of highly heated acid magma into contact with an extremely basic rock which had not had time to cool. It is in accord with this idea that we find no phenomena like those under discussion in the smaller granophyre-intrusions of the district, including the dykes and veins, which are of uniformly acid character. We have already seen evidence that the granophyre-magma was intruded before the beginning of crystallization in it, and therefore in a highly heated condition. On the other hand, it is probable that its temperature was not very much higher than the minimum thus implied, for the fact that the dissolved basic material was not diffused through the whole magma, but remained near the margin, seems to indicate a certain degree of viscosity.

The only instance that I have found, of an unusually dense and presumably basic variety of the granophyre in the interior of the mass, is in the face of the Scurth opposite the 'Apronful of Stones' marked on the 6-inch map. The specific gravity here was found to be 2·814. This may possibly be due to the absorption of an enclosed portion of Eycott lava. Near the same spot I collected specimens which seemed in the field to represent such an inclusion in a highly altered condition, but, if this be their true nature, the metamorphism is too great to admit of any confident identification.

[1] 'Lehrbuch der Petrographie,' 2nd ed. vol. i. (1893) pp. 593–602.

Without much success I have examined the accounts of several foreign areas for phenomena corresponding with those seen at Carrock Fell. The Lake Superior region at once suggested itself as one in which both gabbros and acid rocks are largely developed, the latter being apparently as a rule posterior in date to the former. The varied groups of gabbros, which there occupy large tracts of country and have been described by several American geologists, offer some curious points of resemblance to the Carrock Fell gabbros. Among these features may be mentioned the wide variations met with in the group as a whole, the local variations marked by differences in the relative proportions of the several constituent minerals, the banded or quasi-stratified arrangement of different types in some localities, the existence of ultrabasic modifications extraordinarily rich in titaniferous iron ores, and the presence in other varieties of orthoclase and micropegmatite. The acid rocks, described under such names as augite-syenite, soda-granite, quartz-keratophyre, 'red rock,' etc., are characterized sometimes by biotite, sometimes by augite. Structurally a large number of them seem to be granophyres, and to agree very closely with Lake District examples.

At one locality, Pigeon Point in Minnesota, Mr. W. S. Bayley has described some remarkable features at the junction of an olivine-gabbro with a granophyre ('quartz-keratophyre').[1] Between the two there occurs a zone of rocks chemically intermediate between them and becoming progressively more basic from the side of the granophyre to that of the gabbro. From his examination the author regarded 'the intermediate rock as due to the fusion and re-crystallization of the materials of both the [granophyre] and the gabbro, in consequence of the irruption of one of these rocks into the other at some considerable depth below the surface of the earth, where the conditions were such as to produce a rock with the characteristics of a plutonic rock.' Subsequently he modified this view, and came to the conclusion that the granophyre 'is a product of contact-action between the gabbro and the bedded rocks,' and has arisen from the fusion of the latter (slates and quartzites).[2] The field-evidence on which this change of opinion is based seems to be by no means convincing, and I venture to think that the author's earlier conclusion is not seriously shaken. It may be remarked that, whatever the interpretation of the facts may be, Pigeon Point is probably not the only place where such relations will be found. Bayley points out that the red rocks which R. D. Irving styled augite-syenites, etc., are in part like the normal granophyre of Pigeon Point, in part like the intermediate types there observed, and those of the latter division 'are always, so far as could be determined, in close association with gabbro.' Some of the rocks figured by Irving[3] closely resemble slides in my collection from the basic margin of the Carrock Fell granophyre, though not its most basic part.

[1] Amer. Journ. Sci. ser. 3, vol. xxxvii. (1889) pp. 54–63.

[2] *Ibid.* vol. xxxix. (1890) pp. 273–280.

[3] 'The Copper-bearing Rocks of Lake Superior,' Monogr. U.S. Geol. Surv. vol. v. (1883). See especially pls. xiv., xv.

Mr. Bayley has kindly sent me a few specimens of the Pigeon Point rocks for comparison with my own. So far as can be judged from these, the relations may well be the same in the two districts. The red rock is a granophyre differing from that of Carrock Fell in having biotite instead of augite, and in containing idiomorphic crystals of quartz as well as of plagioclase. In one slide the micrographic intergrowth which makes up the bulk of the rock is on a very minute scale, and passes into what I have styled the cryptographic structure. The 'intermediate' rocks, as in the Carrock Fell district, are somewhat coarse in texture. They are granophyres, in that they have a groundmass of felspar and quartz with micrographic arrangement, but in other respects they differ from the 'red rock.' Iron ores and apatite have come in rather abundantly, and biotite is now only subordinate, the dominant ferro-magnesian mineral in the slides examined being an augite with basal lamellation and 'herring-bone' structure.

[Prof. Sollas has worked out very thoroughly the modification of a granophyre-magma by the absorption of basic material in the case of the numerous dykes which traverse the gabbro of Barnavave, Carlingford.[1] The action of the acid magma upon the derived crystals is much more clearly exhibited there than in the rocks which I have studied. The relations between the earlier gabbro and the later granophyre are evidently different in the two areas. At Barnavave the gabbro appears to have been traversed by contraction-joints and fractured by earth-movements before the injection of the granophyre; and, in consequence of this and of a miarolitic structure in the gabbro, the acid magma was able to penetrate the basic rock in an extraordinarily intimate manner. Prof. Sollas gives reasons for believing that the 'granophyric gabbro' of Barnavave has been produced from ordinary gabbro by this process of impregnation, and suggests that the same explanation may apply to Carrock Fell. According to my observations, however, such action does not there extend to more than a foot or two from the well-defined line of junction with the main body of granophyre, while the quartz-gabbro constituting the central part of the basic intrusion gives evidence of an entirely different origin.—March 2nd, 1895.]

Part III. The Grainsgill Greisen.

13. Description of the Greisen and its Relation to the Granite.

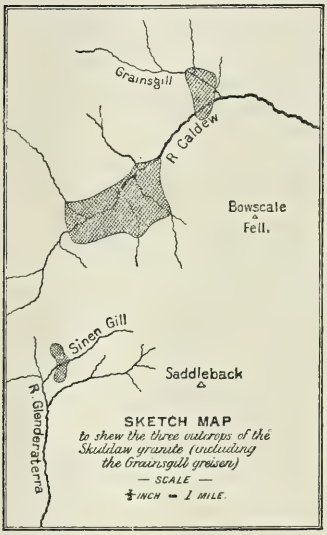
The quartz-mica rock which is here styled 'greisen' is, as already intimated, a peculiar modification of the Skiddaw granite, and the simple course in describing it will be to treat it at once from this point of view.

The well-known Skiddaw granite is seen in three isolated but neighbouring exposures, each at the bottom of a valley and with the appearance of underlying the surrounding slates with a quasi-

[1] 'On the Volcanic District of Carlingford and Slieve Gullion:—Part I. On the Relation of the Granite to the Gabbro of Barnavave, Carlingford,' Trans. Roy. Irish Acad. vol. xxx. (1894) pp. 477–512.

horizontal surface of junction. This feature and the general similarity of the several outcrops make it probable, as surmised by Ward, that the three are parts of a single mass, which must then extend from S.S.W. to N.N.E. for a distance of at least 4 miles. The most southerly exposure is in Sinen Gill, a tributary of the Glenderaterra, on the west side of Saddleback; the next and most extensive is in the Caldew valley, near Wiley Gill and Burdell Gill; the third, with which we are more immediately concerned, is lower down the same valley, near the junction of Grainsgill with the river Caldew. Ward's fourth area, consisting of 'poorly developed' or 'bastard granite,' at the head of Brandy Gill, I find to be an intrusion of granophyre which has no connexion with the Skiddaw granites.

Fig. 2.



The rock of the first and second exposures calls for no special remark. It is essentially a biotite-granite, consisting of orthoclase, oligoclase, quartz, and brown mica. The last encloses numerous little zircons, each surrounded by its characteristic halo of intense pleochroism, which is very conspicuous even when the mica is much decomposed. It must be remarked, however, that, in addition to the magnesian mica, there are often scattered flakes of muscovite, which are always subordinate and not constant enough to be regarded as an essential constituent. The quartz is in part enclosed by the felspar or, in places, roughly intergrown with it.

Coming now to the third area of granite, and beginning with its southern portion, as seen in the bed of the river, we notice a certain difference. The rock is somewhat more acid, yielding 77·26 per cent. of silica as compared with 75·223,[1] and its specific gravity has diminished from 2·624 to 2·604. With this we find that white

[1] In addition to the other gentlemen named above, I am indebted to Mr. A. Harden, of Owens College, Manchester, who has superintended the determination of several silica-percentages in his laboratory. One of these is indicated by the letter M in the following list:—

(i) Granite, White Gill: Silica 75·223 (Hughes).
(ii) Granite, bed of Caldew, 300 yards above junction with Grainsgill Beck: Silica 77·26 (S); sp. gr. 2·604.
(iii) Greisen, near foot of Brandy Gill: Silica 78·13 (M); sp. gr. 2·646, another specimen 2·669.
(iv) Greisen, eastern slope of Combe Height, 250 yards south of Grainsgill Lead-mine: Silica 80·36 (Spencer); sp. gr. 2·684.
(v) Greisen, small inlier in Grainsgill Beck, 400 yards above junction with Brandy Gill: Sp. gr. 2·682.

mica has become an essential constituent, occurring frequently in parallel intergrowth with the brown. Besides this mica, clearly original, there are in places many minute scales developed in the interior of the felspar-crystals in a manner suggestive of secondary change. Part of the quartz is enclosed by orthoclase, or tends to form with it a rude graphic intergrowth.

In the road, less than 100 yards farther north, the white mica is seen to be somewhat more abundant, but the rock is too much decomposed for examination. Going northward up the hill which occupies the angle between Grainsgill and the Caldew, we see no more exposures for nearly 100 yards, during which the character of the rock has completely changed. Biotite has disappeared, and the rock is seen to be composed essentially of quartz and white mica. The microscope shows that a little orthoclase still occurs, though in very subordinate quantity. Much of the mica is not strictly colourless in sections, but has a yellowish tinge with faint pleochroism. The mineral occurs in two ways: firstly, as flakes of some size, but of rather irregular contour and often moulding the quartz and felspar; and secondly, as densely packed little scales, which, with quartz, form more or less defined patches, and may be imagined to represent felspar-crystals. The bulk of the quartz occurs as an irregular mosaic traversed by subparallel rows of fluid-pores, which contain bubbles and sometimes minute crystals [1887].

On the crest of the slope the rocks have the same general character. Felspar is quite subordinate and sometimes wholly wanting, while the light mica is very plentiful. It occurs in relatively large flakes, in fan-like, sheaf-like, or feathery groupings of smaller flakes, or in aggregates of minute scales, and is very pale to colourless in sections. Much of the rock exposed here has a porphyritic aspect, due to the development of large grains of quartz. In another type the quartz-mosaic becomes rather coarse-textured, the mica occurs only in rather large flakes, and the rock has more of the character of a true greisen. My friend Mr. L. J. Spencer, now of the British Museum (Natural History), has had the kindness to analyse this rock, and his results are given below, side by side with Mr. Hughes's analysis of the normal Skiddaw granite:—

	IV.	V.
SiO_2	75·223	80·36
Al_2O_3	11·140	11·12
Fe_2O_3	trace	1·77
FeO	1·771	
MgO	1·081	0·56
CaO	1·624	0·67
Na_2O	3·996	1·82
K_2O	4·516	2·47
Loss on ignition	0·500	1·96
P_2O_5	0·149	—
	100·000	100·73

IV. Skiddaw granite, White Gill (see Ward, Q. J. G. S. vol. xxxii. 1876, p. 5).
V. Greisen, eastern slope of Combe Height, 250 yards south of Grainsgill Lead-mine: sp. gr. 2·684.

As compared with the normal granite, the percentage of silica in the greisen shows an increase of about 5, while the figures for magnesia, lime, and the alkalies are about halved. Mr. Spencer's analysis shows that some of the mica must be of a soda-bearing variety, and most of the iron can be contained only in the same mineral, accounting for the yellowish tinge already mentioned.

Quartz-mica rocks with the same general characters as the above occupy the slope down to Grainsgill, and are seen in the beck and again in the lower part of Brandy Gill, encasing the lode which has there been mined for lead. In Grainsgill Beck similar rocks are seen eastward as far as the foot of Poddy Gill, where they are in contact with very highly metamorphosed Skiddaw Slates. Westward they extend about 250 yards above the junction with Brandy Gill, and re-appear in a small inlier in Grainsgill Beck about 150 yards farther. The rock here resembles that analysed.

On the hill-side south of Grainsgill the greisen is traversed by numerous veins of quartz and mica, from 1 inch to 1 foot in thickness, and some few of these also traverse the adjacent metamorphosed rocks. Quartz forms the bulk of each vein, the grey mica occurring sometimes in patches or pockets, sometimes in distinct seams, where the flakes are often grouped into rosette-like aggregates. Rarely the veins contain a few crystals of tourmaline: topaz and tinstone seem to be wholly absent.

14. Possible Cause of the Modification.

It will be seen from the foregoing account that these Cumbrian quartz-mica rocks differ in some respects from typical greisens, such as those of Cornwall and Saxony. On the other hand, they present some points of resemblance to the remarkable rocks in the Urals to which Gustav Rose gave the name beresite.[1] As described by Arzruni,[2] the latter consists essentially of white mica[3] and quartz, sometimes alone, sometimes with more or less orthoclase and plagioclase. The mica occurs in two habits, and is distinguished by Arzruni as primary and secondary. Other peculiarities of our rocks, such as the porphyritic quartz-grains and the quartzose veins, are also paralleled in the Russian rocks. The typical beresite, however, is richer in mica than the Grainsgill rocks: a non-felspathic example, from Beresowsk itself, yielded only 64·41 per cent. of silica, and was calculated to contain nearly 63 per cent. of mica. For this and other reasons I have preferred the name 'greisen' to that of 'beresite' for the rocks here described, while noting their difference from the better known type of greisen. In the beresites of the Urals, as in the rock of Grainsgill, topaz, tinstone, and other

[1] 'Reise nach dem Ural' (1837–42), vol. i. p. 186, vol. ii. p. 557.

[2] Zeitschr. Deutsch. geol. Gesellsch. vol. xxxvii. (1885) pp. 865–896. An earlier description by Karpinsky (1875–76), written in Russian and not very easily accessible, is summarized by Arzruni.

[3] This may include both muscovite and paragonite. In the only chemical analysis of the rock, by Karpinsky, the alkalies are not separately determined.

minerals characteristic of the true greisens are absent, and argentiferous galena is found. Arzruni gives a long list of other minerals from the mines of Beresowsk and neighbourhood,[1] only a few of which are known in our area. The beresite is the 'country' rock of the gold of the Urals.[2]

These Russian beresites form a system of broad bands, the relation of which to the normal granite of the district has not been clearly set forth. In the case of the Grainsgill rock the field-relations are scarcely open to question. The granite and the greisen form parts of a single intrusive body, and there is a transition, at first gradual, but ultimately more or less abrupt, from the former rock to the latter. The appearance is therefore as if the greisen had been 'extruded' from the granite, and a comparison is at once suggested with pegmatites such as those described by Mr. Barrow[3] in association with the igneous gneisses of Forfarshire and the neighbouring counties. Although these Highland rocks are richly felspathic, while the Cumberland greisen is almost free from felspar, a comparison of specimens brings out some curious points common to the two, such as the plumose arrangement of white mica which Mr. Barrow considers characteristic of his pegmatites. Again, the description of the Grainsgill rock given above has already suggested that the abundant minute flakes of mica may have been produced, in conjunction with quartz, by the destruction of felspar once present in the rock. The large flakes and plumose aggregates of mica, the porphyritic grains of quartz, and some other peculiarities which must date from the epoch of consolidation, preclude the supposition that the greisen is merely normal Skiddaw granite transformed by secondary metasomatic changes or by the agency of 'mineralizers' as a last phase of the igneous activity; but it is at least a tenable idea that the Grainsgill rock bears the same relation to a pegmatite of the Forfarshire type that the Cornish greisen does to its associated granite.

However this may be, it is significant to note, in another district, a greisen like that of Grainsgill and a pegmatite like those of Forfarshire occurring together and holding identical relations towards the granite, with which both are intimately connected During a recent visit to the Isle of Man, I had an opportunity, in company with my friend Mr. G. W. Lamplugh, of examining the granite of Foxdale. This rock, also intruded among Skiddaw Slates, is a muscovite-granite identical with some of the Leinster granites, on the axis of which it occurs. It consists of quartz, microcline, an acid plagioclase, muscovite, subordinate biotite, and little crystals of garnet and zircon. In the marginal part of the intrusion are developed bands and masses of pegmatite, thick veins and bands of

[1] See list by Kokscharow in Murchison's 'Geology of Russia,' vol. i. App. E (1845), pp. 640–645; also H. Louis, 'On the Mode of Occurrence of Gold,' Mineral. Mag. vol. x. (1893) pp. 241–247.

[2] See Murchison, De Verneuil, and Keyserling, 'Geology of Russia and the Ural Mountains,' vol. i. (1845) pp. 476, 477.

[3] Geol. Mag. 1892, pp. 64, 65; Quart. Journ. Geol. Soc. vol. xlix. (1893) pp. 330–337.

greisen, and finally quartz-veins containing only local aggregations of white mica or bordered by a narrow seam rich in that mineral. These quartz-veins, as at Grainsgill, traverse the other types of rocks.

Returning to the Cumbrian area, we note that the greisen occurs on the north side of an outcrop of granite, which is probably in subterranean continuity with the other outcrops to the south-west and south. In other words, it forms a fringe on the northern border of the large body of Skiddaw granite, though whether such fringe occurs on the northern edge only is a point on which we have no positive evidence. Regarding it as a modification of the granite, we see that, apart from subsequent chemical transformations, it must be due in the first place to some process of differentiation radically unlike any which have been discussed above. The cause of this differentiation was probably that advocated by Mr. Barrow in the case of his pegmatites, namely, mechanical force operating on the granite-magma when crystallization had already proceeded in it to a certain stage.

The Skiddaw granite, including the greisen,[1] has produced foliation on the cleavage-planes of the adjacent slates, and therefore belongs to the later group of igneous intrusions, to which also the other Lake District granites, those of Eskdale and Shap, must for various reasons be referred. From a general study of the district we are led to believe that all these intrusions, though in great part later than the cleavage, are intimately connected with the great post-Silurian crust-movements of which the cleavage-structure is only one manifestation. The forces by which these movements were produced were directed from south to north, and it is in this direction that the fringe of greisen- (or pegmatite-) magma seems to have been thrown out from the partially consolidated Skiddaw granite. If, when the zircon, the biotite, and part of the felspar had already crystallized, a portion of the still fluid 'mother-liquor' was squeezed out, it is clear that the partial magma thus forced northward would be of more acid composition than the granite as finally consolidated from the remainder, and would give rise by its crystallization to a rock of different type. How far the chemical difference between the granite and the greisen is thus accounted for, or how far that difference must be ascribed to subsequent chemical modification of the fringing rock, is a question not easily solved.

It may be remarked in passing that any connexion established between crust-movements and differentiation in rock-magmas must have a most important bearing on the problem of the geographical distribution of different types of igneous rocks in 'petrographical provinces' often divided by mountain-ranges.[2]

[1] The greisen seems to have given rise to more intense and widespread metamorphism than the granite. This extreme metamorphism produced by a very acid intrusion, rich in white mica, is in accord with what is known in other areas.

[2] See 'The Evolution of Igneous Rocks,' in 'Science Progress,' vol. i. (1894) pp. 152–165.

15. Conclusion.

In this and my former communication I have described, and to some extent discussed, some of the striking variations observable in the igneous rocks of the Carrock Fell district. While that area affords special facilities for such a study, it is probable that variations similar in kind, and perhaps in degree, occur among other well-known British rocks. The tendency to select in the field a 'typical' specimen, *i. e.* one similar to those already exhibited in museums or obtained by dealers from some particular quarry, has perhaps caused us to overlook or neglect in many cases the considerable variety of types met with in a single body of eruptive rock.

As regards the cause of the phenomena, enough has been said to show that many different considerations may legitimately enter into speculation on the subject. The most important kinds of variation described in the foregoing pages are:

(i) The increasing basicity of the gabbro from the centre to the margin of the intrusion, which is explained by a *concentration* of the basic elements in the cooler portion of the magma during the progress of crystallization.

(ii) The relatively basic modification of the granophyre at its junction with the gabbro, ascribed mainly to an *incorporation* of re-fused ultrabasic gabbro into the granophyre-magma.

(iii) The passage of the Skiddaw granite into a remarkable quartz-mica rock, which is perhaps a result of *mechanical pressure* operating on the granitic magma during its period of crystallization, but complicated by later metasomatic processes.

Some minor kinds of variation have also been noticed, and a study of the numerous dykes and veins, belonging to the latest phase of igneous activity at Carrock Fell, would doubtless bring out further points of interest.[1]

Nothing has been said of possible differentiation in igneous magmas prior to their intrusion, this being a matter of somewhat remote inference rather than a deduction from observation. It may be remarked, however, that all the results arrived at are consistent with the hypothesis that the gabbro and the granophyre were formed by magmas which were themselves partial magmas derived by differentiation from a common source. Such an idea is indeed suggested, not only by the close association of the two rocks, but also by their chemical composition. The similarity underlying their differences may be partly exhibited by a diagram analogous to those used by Iddings and others, in which the molecular proportions of silica and of the several bases are taken as abscissæ and ordinates respectively. I have preferred, however, to plot the atomic proportions of the corresponding elements, instead of the molecular proportions of the oxides; by this plan the several

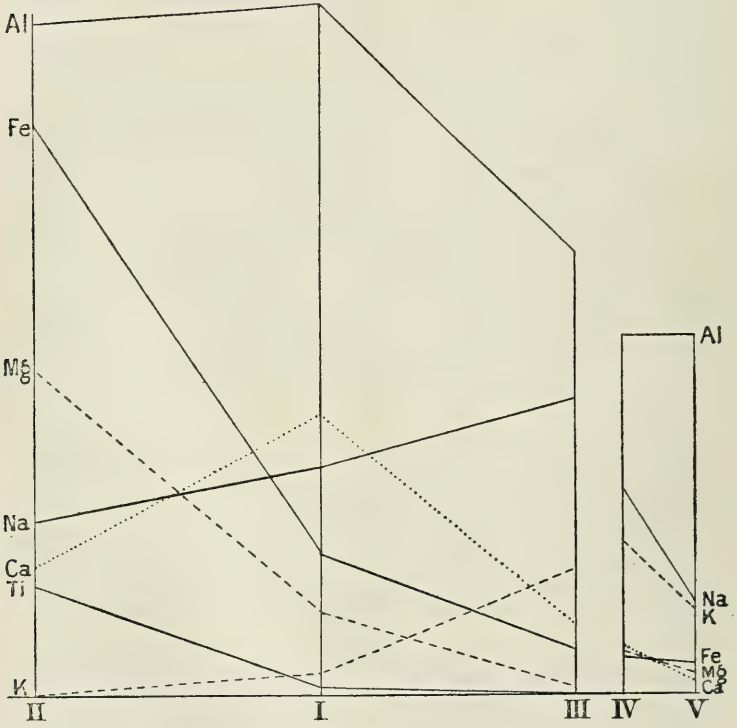
[1] See Geol. Mag. 1894, pp. 551–553.

curves are more distinctly separated, and the two iron oxides are united as metallic iron. The Roman numerals in the diagram refer to the chemical analyses given in the text, namely :—

II. Iron-ore gabbro.
I. Normal quartz-gabbro.
III. Granophyre.

The 'consanguinity' of the several rocks is thus clearly brought

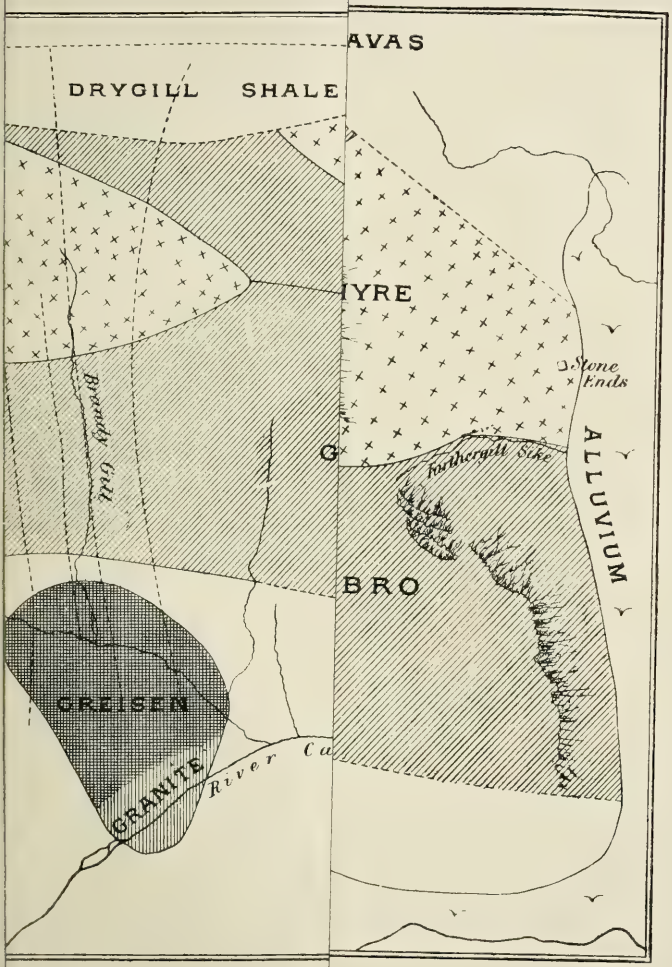
Fig. 3.—*Diagram showing the atomic ratios of the several constituents in the rocks of the Carrock Fell district.*

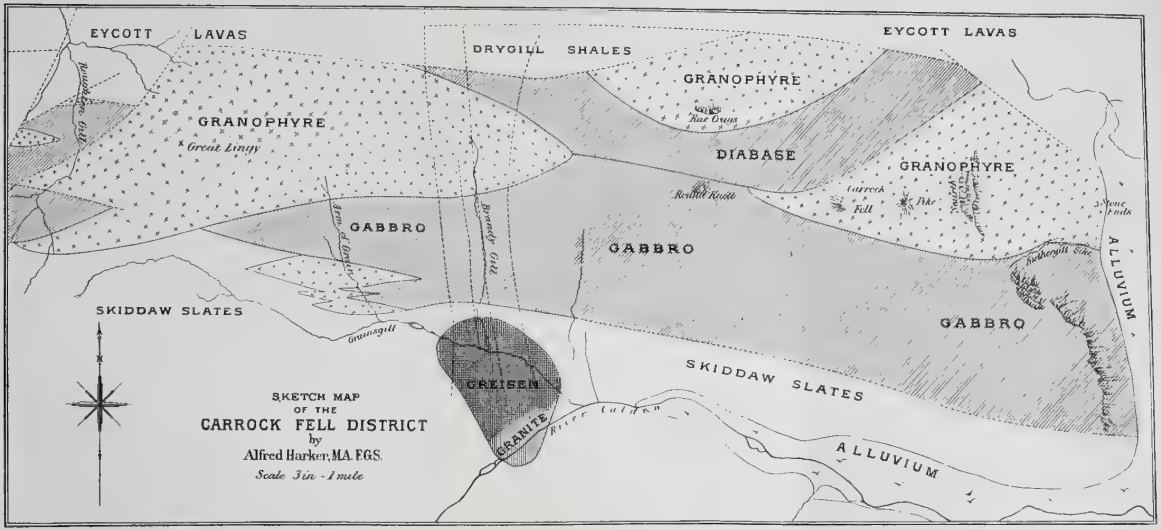


out. The Skiddaw granite, as already stated, probably belongs to a quite distinct group of intrusions. This also is illustrated by the diagram, which shows :—

IV. Skiddaw granite.
V. Grainsgill greisen.

The similarity of the greisen to the granite is apparent, but to bring them into connexion with the other group would require


AVAS
DRYGILL SHALE
IYRE
Stone Ends
Brandy Gill
Fothergill Sike
ALLUVIUM
BRO
GREISEN
GRANITE
River Ca


EYCOTT LAVAS
DRYGILL SHALES
EYCOTT LAVAS
GRANOPHYRE
GRANOPHYRE
Great Lingy
Rae Crag
DIABASE
GRANOPHYRE
Carrock Fell
Tarn
Round Knott
Stone Arks
GABBRO
GABBRO
GABBRO
ALLUVIUM
SKIDDAW SLATES
SKIDDAW SLATES
GREISEN
GRANITE
ALLUVIUM
SKETCH MAP
OF THE
CARROCK FELL DISTRICT
by
Alfred Harker, M.A. F.G.S.
Scale 3 in. = 1 mile.

some rather unnatural zigzags, particularly in the aluminium- and magnesium-lines.

[Prof. Brögger has pointed out (Vidensk. Skr., math.-naturw. Klasse, 1894, no. 4, p. 196) a misconception underlying my statement in Quart. Journ. Geol. Soc. vol. l. p. 326, that the phenomena of differentiation described by him 'differ in a fundamental respect' from those of the Carrock Fell gabbro. He distinguishes two kinds of differentiation, *tief-magmatische* and *lakkolithische*; and the contrast which I drew should apply only to the former of these. The latter, or, as it is called in his paper on Gran, 'differentiation in the bosses,' is in no essential respect dissimilar to that described by me at Carrock Fell.—January 25th, 1895.]

EXPLANATION OF PLATE IV.

Sketch-map of the Carrock Fell district (scale: 3 inches = 1 mile), showing the distribution of the gabbro and diabase and of the granophyre; also the greisen of Grainsgill. The Skiddaw Slates, the Eycott Lavas (part of the Volcanic Series), and the Drygill Shales (belonging to the Coniston Limestone Group) are left blank.

The boundaries, especially in the western portion, where exposures are few, are often in part conjectural. The broken lines indicate faults.

Discussion.

Sir Archibald Geikie, complimenting the Author upon the skill with which he had worked out his subject, remarked that the summary of the paper, as expounded at the Meeting, was so condensed that criticism was hardly possible until the full paper was in print. There were only two points on which he would ask for further information. In the first place he wished that the Author would state whether he had any evidence of the date of the gabbro and granophyre-protrusions of Carrock Fell: they were admittedly much younger than the granite and greisen of Skiddaw. In the second place, he asked whether, among the various structures of the granophyre described by Mr. Harker, there was any distribution with reference to position in the body of the rock, and in particular whether any distinctive structures were observable in the marginal portion of the granophyre where it impinged upon the gabbro, which it had partly incorporated into itself.

Mr. Teall said that he had paid a short visit to the district some time ago, and had come away with the impression that there were transitions from gabbro to granophyre. The Author's more detailed observations proved that he (the speaker) must have been mistaken. He fully agreed with the Author as to the intimate relation between micropegmatitic and spherulitic structures. He considered that the microfelsitic spherulites of Rosenbusch were submicroscopic intergrowths of quartz and felspar. The greisen of Grainsgill appeared to be essentially distinct from that of St. Michael's Mount, Cornwall. The latter contained topaz, and was clearly due to an alteration of

the granite by vaporous exhalations or solutions acting outwards from ordinary joint-planes.

Prof. J. W. JUDD, Mr. J. E. MARR, Mr. GEORGE BARROW, and Mr. W. W. WATTS also spoke.

The AUTHOR thanked the speakers for their reception of his paper, and briefly replied to some of the questions raised. As regards the age of the gabbro and granophyre, he had not been able to come to any precise conclusion, but stratigraphical considerations indicated that these rocks were intruded subsequently to the post-Silurian crust-movements. The granite and greisen belonged to the epoch of those crust-movements. The granophyre showed structural as well as mineralogical modifications in the neighbourhood of the gabbro, assuming in places a singularly coarse texture. The rock which he had termed 'greisen' certainly differed from the rocks so named in Cornwall, and, in particular, it carried none of the special minerals so characteristic of the latter.

16. *The* Geology *of the* Country *around* Fishguard, Pembrokeshire. By F. R. Cowper Reed, Esq., M.A., F.G.S. (Read January 23rd, 1895.)

[Plates V. & VI.]

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I. Introduction.

On the northern coast of Pembrokeshire there lies a district of considerable area which has not been geologically investigated since the completion of the Government Survey under De la Beche in South Wales. The region adjoining that to be described in this paper has been made known to us in detail by the labours of Dr. Henry Hicks and others during the last few decades; and we may therefore claim a fairly complete acquaintance with the Archæan, Cambrian, and Ordovician rocks of South-west Pembrokeshire. North-east of a line running from Penclegyr Point on the coast inland to St. Elvis in the south, we have had, however, to confess comparative ignorance.[1] The Geological Survey memoir on South Wales pays scant attention to this district, and relatively little information of importance can be obtained from any subsequent geological literature.

My object in visiting this tract of country was to determine the age of the volcanic series indicated on the Survey map near the

[1] Murchison mentions the 'trap rocks' near Fishguard in his 'Silurian System' (1839), pt. ii. p. 401; and De la Beche in a note to his 'Geology of Southern Pembrokeshire,' Trans. Geol. Soc. ser. 2, vol. ii. pt. i. (1826) p. 3.

coast, and to investigate the characters of both the contemporaneous and intrusive igneous rocks in the field and laboratory. To petrological questions, therefore, special attention has been paid.

The area with which this communication deals extends from Newport in the east to the western side of Strumble Head in the west, and lies north of a line drawn from Pwll Crochan to Cilgwyn, and passing through St. Nicholas and Llanllawer. This narrow strip of country, it will be noted, approximately coincides with the strike of the beds. (See Map, Pl. V.)

II. Structure of the District.

The general geological structure is readily understood on examining the 1-inch Geological Survey map. West of Fishguard town Llandeilo rocks, with apparently a general east-and-west strike and northerly dip, occupy most of the ground. A conspicuous wedge-shaped outcrop of 'felspathic ashes and traps' runs from the north-east point of Pen Caer in a south-westerly direction past Goodwick to a point near St. Nicholas, where it tapers out and disappears.

Other masses of similar rocks are indicated at Porth Sychan, on Castle Point, on the coast towards Dinas, as far as Aber Richard; and a band extends from Bwlch Mawr in the west to a point south of Aber Rhigian, while an isolated patch is seen at Carn Ffoi.

Large masses and bands of intrusive 'greenstone' are marked in: one enormous mass extends along the north coast of Pen Caer in a broad belt, and sends off a strong spur to the south through Llanwnda. Another considerable mass crosses the centre of the headland from Pwll Deri to Y Garn; while east of the town of Fishguard, and farther on towards Newport, sheets and lenticular patches range more or less parallel to the strike of the strata into which they have been intruded.

The slaty beds are stated to be of Llandeilo age, and 'altered Llandeilo' rocks form two contact-zones. Such is the information that we gather from a brief examination of the Geological Survey map.

In the sketch-map accompanying this paper (Pl. V.) some slight modifications have been found necessary. Firstly, in the place of the zone of 'altered Llandeilo' on the north of the Pwll Deri—Y Garn intrusive mass, a tract of volcanic rocks is inserted. A small patch of similar rocks has also been found on the northern side of Porth Melyn, near Pwll Deri, in the midst of the 'greenstone.' Secondly, the 'interbedded felspathic traps and ashes' of Castle Point, Fishguard, have been found also on the western side of the harbour and crop out again at Bigney, in Cwm Brandy, in Cwm Bach, and on Manorowen Hill; and possibly the conspicuous rugged knobs of Carn Llys, $\frac{1}{2}$ mile S.E. of St. Nicholas, are a continuation of the same beds. But the great variation in volcanic beds of the same geological horizon, when traced along their strike, is markedly illustrated in this area, and renders the identification and correct

assigning of the scattered outcrops to their proper horizons a matter of difficulty and uncertainty. The exposures at Trefelgarn and Carn Llys are examples. Small local disconnected flows issuing from different vents on approximately the same horizon seem a reasonable explanation of this variation.

Above and in close connexion with the Castle Point lava-flows are certain greenish-grey fossiliferous ashes, exposed within the old fort on this Point and on the slopes outside of it. On the Geological Survey map only greenstone is there indicated. These ashy beds strike across the mouth of the harbour and occur on Saddle Point.

The Carn Ffoi mass of volcanic rocks is found to be not an isolated block, but a portion of the same broad belt that is conspicuous near Bwlch Mawr; this belt has been traced eastward, south of Newport town, to the banks of the river Clydach.

The separation of the closely intruded sheets of diabase in the Llanllawer and Carn Ingle district must be to a large extent arbitrary, in the absence of definite field-evidence. I do not see sufficient cause to justify mapping them in so many narrow parallel sheets as are indicated on the Survey map; at any rate the ground is now completely overgrown, and the solid rock is rarely exposed at the surface.

III. Folds, Faults, etc.

On Pen Caer the strike of the beds is generally E.N.E. and W.S.W., but east of Fishguard, and near Newport, it changes gradually to nearly due east and west. The disturbance in the strike on Pen Caer seems, to some extent, due to the intrusion of the huge mass of diabase.

The dip of the beds is to the north or N.N.W. at high angles (60° to 80°). Comparatively little folding on a large scale appears to have taken place; but round the cliffs of Fishguard Harbour and on the steep bank by the road connecting Upper and Lower Fishguard the slates have been thrown into numerous small folds, and exhibit small normal and reversed faults.

The contorted strata in the cliffs of Dinas Head have been figured in the Geological Survey memoir, and the plications in similar beds are noticeable near Newport. Instances of local flexures are frequent in the cliffs where the latter are composed of slates, and many are marked on the Geological Survey map.

The faults in this area are not numerous. The most important one runs from Pwll Ceunant, which is on the coast between Fishguard and Dinas Head, in a south-easterly direction past Cilshafe and Llanllawer. By means of it the Upper Llandeilo Beds between Pwll Ceunant and Newport are shifted back southwards, the downthrow being to the east.

Another fault farther east, with a downthrow on the same side, starts from Cwm Rhigian, and runs with a southerly course towards the farm named 'Parke' on the 6-inch map. This also gives the beds to the east of it a further shift southwards. Both these faults

cut across and displace the intrusive masses, as well as the volcanic beds and the slates.

A small fault runs across the north-eastern corner of Pen Caer in a W.N.W.–E.S.E. direction, and cuts the coast on Pen Fathawg, where it can be well seen, and again between Crincoed Point and Pwll Hîr.

An extensive fault, starting from Penrhyn, on the shore near Goodwick, runs in a W.S.W. direction towards Carn Gelli; on the S.E. side it drops down the volcanic breccias which are stratigraphically above the lavas. The beds are here nearly vertical, and so is the hade of the fault, but the trend of the latter makes a slight angle with the strike of the beds, and therefore truncates them. On the S.E. side of this faulted mass of breccia another fault cuts out the underlying lavas, and runs in a S.W. course along the valley. The beds of breccia and ash strike against this fault at an angle of between 20° and 30°. The impersistent and lenticular character of the volcanic beds renders its course somewhat obscure, but the lavas at Ffynnon Druidion appear to be the underlying series.

IV. Relation of the Form of the Ground to the Geological Structure.

The highest ground is occupied by the diabase-masses, which rise into rough and rugged eminences with bare craggy summits, somewhat resembling the Devonshire tors. On Mynydd Llanllawer, Garn Fawr and Carn Enoch are good examples, while on Strumble Head the line of 'tors' stretches from Pwll Deri to Pont Iago, and Carn Wnda is a prominent object for many miles round. Near Newport the most important elevation—Carn Ingle—consists also of 'greenstone.' Where the felspathic element predominates over the ferro-magnesian the rock weathers white, instead of the commoner greenish-brown: Garn Fechan and the eastern slopes of Carn Ingle are instances.

The flinty volcanic rocks, whether tuffs, breccias, or lavas, weather with a white crust and occupy high ground, though not rising to such elevations as the intrusive diabases, etc. More numerous detached fragments, more angular outlines, thinner soil, and the white crust characterize them in the field.

For the most part the low-lying ground is composed of the slaty beds; and these tracts, being enclosed for pasture-land, or covered with swamps, or cultivated for crops, afford no exposures of the solid rock. Usually, moreover, drift or Boulder Clay causes an additional difficulty in tracing the boundaries or determining the characters of the underlying beds. The cliffs east of Coch y Ceiliog afford good sections of the slates, and their sharp ridges and jagged reefs that run out into the sea, with their outlying stacks and islets, exhibit markedly different outlines and shapes from those composed of the igneous materials.

The river Gwaen, which drains most of the district east of Fish-

guard, flows along a deep valley excavated in the strike of the slaty beds for the greater part of its course; but west of Llanychaer it cuts across the strike, and has sawn its way through the diabase-sheets before it reaches the sea in Fishguard Harbour.

The wide silted-up estuary of Goodwick Bay is now a swamp traversed by a few sluggish, unimportant streams. It is not improbable that a slight rise of the coast has taken place in recent times, and that this has helped in blocking up the mouth of these streams. The former insular condition of Dinas Head—which is separated from the mainland merely by a peculiar trench-like valley now never occupied by the sea, though only a few feet above the sea-level—points to an uplift along the coast to the extent of a few feet; the 'Slade' at Fishguard likewise appears to have been formerly a sea-inlet, and the character and shape of its banks and of the sides of the Dinas valley look as if they were due to marine denudation rather than to subaerial waste. The structure and relations of the watercourses, tunnels, and rocky platforms at Pwll y Wrâch (the Witches' Cauldron), on the coast between Newport and Cardigan, seem to require for their explanation a change of sea-level in comparatively recent times. It is premature to go further than to throw out a suggestion on this point; the subject offers, however, a promising field for investigation.

The watershed between the Gwaen and Clydach rivers is very low, and the exact point at which the waters divide to flow in opposite directions is near Llanerch, S.W. of Cilgwyn, in a narrow gorge. The Clydach is a transverse stream, with its course lying across the strike of the strata; it falls into the Nevern about ½ mile east of Newport town. The drainage of the northern slopes of the high ground is conducted into the sea by short transverse streams opening into such bays as Aber Rhigian, Aber Fforest, Aber Bach to the east of Fishguard, and Aber Felin and Porth Sychan on Strumble Head.

The lines of greatest elevation follow the outcrop of the igneous rocks, culminating in Garn Fawr in the west, which rises into a bare rugged hill 699 feet high, and in Carn Ingle to the east reaching a height of nearly 1200 feet. The whole of the Llanllawer Mountains (Mynydd Melyn, Parc Mawr, Mynydd Caregog, etc.) forms a ridge between 800 and 1100 feet high, averaging about 950 feet for the greater part of its length. Its abrupt termination east and west is due to the thinning-out of the lenticular masses of intrusive rock.

V. Stratigraphy and Petrography.

(*a*) The Sedimentary Rocks.

Though slaty rocks are abundant in this area, they rarely crop out on the surface inland; in the sea-cliffs, on the other hand, fine sections are exposed, but, unfortunately, they are very barren of organic remains, despite the fact that many of the beds possess a very favourable appearance for the preservation of fossils. In the

coast-sections between Fishguard and Newport I have failed to find any fossils, and inland my search has been successful in only a few instances.

The lowest beds in the district are the slates between Goodwick Bay and the Pwll Ceunant—Llanllawer fault. These occupy approximately all the ground south of Fishguard town. They are black to bluish-black tough slates, splitting into fairly large slabs. Since in the upper portion of these slates Llanvirn fossils have been obtained, in quite the northern part of their area, it follows that, unless there is repetition by folds or faults, the greater part belongs to the Arenig series. The principal locality at which fossils have been found in these beds is in the Blaen y Delyn quarries and on the adjoining slopes, close to Tower Hill, Fishguard. On beds of the same age stands the town of Fishguard itself. The strata on this horizon have suffered considerable plication, and the small folds and faults can be seen on Tower Hill. To this cause may be attributed the slight admixture of fossils from this locality, for *Didymograptus Murchisoni* is extremely abundant together with Lower Llanvirn (Upper Arenig) forms. The identical appearance of the beds and their mode of preservation make the faunal facies the only means of separating the horizons. The fossils obtained from this locality are the following:—

Orthoceras caeresiense (Hicks).
„ *Avelinii* (Salter).
Caryocaris Marri (Hicks).
„ sp. (Salter).
Ceratiocaris, sp.
Placoparia cambriensis (Hicks).
Æglina binodosa (Salter).
Illænus, sp.

Didymograptus Murchisoni (Beck).
„ „ var. *geminus*.
„ *bifidus* (Hall).
Diplograptus dentatus (Brongn.).
Climacograptus cælatus (Lapw.).
„ sp.

We seem to be just on the junction of the Lower Llandeilo (=Upper Llanvirn) and Llanvirn (=Lower Llanvirn of Dr. Hicks) Beds; for most of the graptolites belong to the former, while the rest of the fossils belong to the latter. The graptolites were determined by Mr. J. E. Marr, F.R.S. The 'tuning-fork' forms are especially abundant.

The age of the beds is definitely fixed by this assemblage of fossils, and they are evidently a continuation of the well-known Llanvirn and Lower Llandeilo Beds of St. David's, first described by Dr. Hicks.

On the strike of these Tower Hill beds exposures of slates of similar character occur on the roadside, 200 yards west of the farm of Maes Gwynne, on the way to Manorowen from Fishguard. The graptolites from these beds were submitted to Prof. Lapworth, who very kindly gave me his invaluable assistance in identifying these badly-preserved fossils. He distinguished three forms:—*Didymograptus Murchisoni*, var. *geminus*, *Cryptograptus tricornis* (Carruthers), *Diplograptus foliaceus* (Murchison),[1] adding: 'These beds are well below the Llandeilo Limestone, and answer to the

[1] This fossil Prof. Lapworth identifies as *D. foliaceus*, 'or, at least, a form which I cannot separate from one of the Llandeilo varieties of the species.'

Llanvirn Beds of Dr. Hicks, or what I should call Lower Llandeilo.' Thus it is seen that this is the same set of beds as that in the Blaen y Delyn quarries. These are the only two localities where fossils have been found in beds below the lower volcanic series, although Mr. H. Keeping and myself have carefully searched the various exposures in the area. The rocks to the south, which must be of Arenig age, have as yet yielded no organic remains.

With regard to the beds above the lower volcanic series, the vertical black slates on the south-eastern side of Goodwick Bay have yielded obscure fossils. These slates contain softer shaly bands, and in one of these soft papery bands of black shale of a very rotten and crumbling character the fossils were found. Fortunately the best-preserved graptolite belongs to the zonal form *Didymograptus Murchisoni*; so we know that we are still low down in the Llandeilo—presumably still in the Lower Llandeilo, for this graptolite is by far the most abundant fossil, the only other recognizable fragment belonging to a *Diplograptus*. These slates strike up the Goodwick valley, and in the quarries near Drim Wood are seen to have taken on a sandy character. They have here suffered considerable crumpling and alteration.

Between these slates and the underlying volcanic series of Bigney, Cwm Bach, etc., some ashy beds are found on Saddle Point and again on the eastern side of Fishguard Harbour, on Castle Point. These beds are of a bluish-grey colour when in an unweathered condition, and are strongly cleaved across the bedding-planes, thus rendering the identification of the fragmentary fossils with which they are crowded extremely difficult. Inside the fort on Castle Point and on the outer slopes of that headland the exposures have yielded recognizable fragments of *Trinucleus concentricus* (var. *favus*?), *Orthis* sp., *Glyptocrinus*? (stem-joints), and fragments of other organisms. On the Geological Survey map these beds are coloured as 'greenstone.' Their age, stratigraphically and palæontologically, is seen to be Lower Llandeilo,[1] and the non-graptolitic facies of the fauna is sufficiently accounted for by the lithological character of the rock.

The volcanic beds that lie below these fossiliferous ashes and above the *D. Murchisoni*-beds of Tower Hill must therefore be wholly in the Lower Llandeilo, and, accordingly, they are stratigraphically slightly higher than the tuff-bed which separates the Llanvirn (Upper Arenig) from the Lower Llandeilo in Abereiddy Bay, as described by Dr. Hicks (*op. cit.*).

These volcanic beds are cut off to the east by the Pwll Ceunant fault: this brings almost against them the great belt of Upper

[1] Certain beds of black shale at the southern end of Ramsey Island, with *Trinucleus*, etc., which are considered by Dr. Hicks to be intermediate between the Llanvirn and Lower Llandeilo, are possibly of the same age. Throughout this paper it has seemed advisable to me to use the term 'Lower Llandeilo' in the sense applied to it by Dr. Hicks in his description of the Abereiddy Bay beds (Quart. Journ. Geol. Soc. vol. xxxi. 1875, p. 177), and to restrict the term 'Llanvirn' to the *Placoparia*-bearing beds, there called by him Upper Arenig.

Llandeilo lavas and ashes, which extends right across the country to Newport and the river Clydach. Near Newport the horizon and succession of the overlying beds is fortunately determinable, so that the age of this great volcanic belt can be definitely fixed. The beds immediately resting on the lavas are grey tuffs, and these are succeeded by tough calcareous slates, on which rest 150 feet or more of dark graptolitic shales. The grey tuffs may reach 50 feet in thickness, as near the 'Rising Sun' Inn on the road from Newport to Cilgwyn. They are found again about $\frac{1}{2}$ mile south of Newport, near Fountain Hill Farm, and also in 'Old Quarries,' about 100 yards south of Pen y Feidr farm, south-west of Newport. At several other localities along their strike, which is nearly due east and west, they are exposed.

The tough slaty beds above them do not attain a thickness of more than 20 feet, and thin calcareous bands occur among them. The only fossils that have been found in them are *Siphonotreta micula* and a cyprid. The brachiopod is very characteristic of the beds with *Ogygia Buchi* at Pen Cerrig, Builth, in the typical Upper Llandeilo.

The graptolitic dark shales, 150 feet or more in thickness, occur above these slaty beds, and are well exposed in the lane from the Castle, Newport, to Fern Hill Cottage. Above these comes the great series of unfossiliferous slates which occupy the whole ground to the coast; and above them the sandstones, slates, and conglomerates of Dinas Head.

With regard to the graptolitic shales, the stratigraphical evidence and the occurrence of *Siphonotreta micula* in beds immediately below them suggest that they belong to some horizon *above* the Llandeilo; for elsewhere, as already mentioned, this brachiopod occurs with the typical Upper Llandeilo trilobite *Ogygia Buchi*. The identification of the graptolites, which Prof. Lapworth kindly undertook, tends to confirm this view. The greatly compressed state in which they occur renders them very difficult of identification, but the following three forms seem to be represented: *Diplograptus euglyphus* (Lapworth), *D. foliaceus* (Murch.), large form, *D. truncatus* (Lapw.), or *D. perexcavatus*.

According to Prof. Lapworth, these appear to be Upper Glenkiln forms, and to belong to a very conspicuous zone in South Wales occurring close below, or in the immediate neighbourhood of the well-known Bala Limestone. At any rate, they are certainly of Bala or of the very highest Llandeilo horizon.

Thus is fixed the age of the beds immediately overlying the upper volcanic series. The latter, therefore, must be at the base of the Upper Llandeilo, and the Middle Llandeilo must be represented by some of the underlying slates, unless it has completely thinned out. That it is thin in this area is indicated by the succession in Goodwick Bay. It is possible that it is wholly or partly represented by the volcanic series, but this seems extremely improbable, since in the adjacent area of Abereiddy Bay there was a complete cessation

of volcanic activity during the deposition of the Middle Llandeilo. No fossils of this period which might enable one to settle the question have at present been discovered in the Fishguard–Newport area.

The great series of barren slates above the Upper Llandeilo graptolitic shales must therefore belong to the Bala, and near Newport they are quite devoid of volcanic material; while the Dinas Head sandstones, etc., would be of Llandovery age. From these Newport slates no fossils were obtained by me, and they are tougher, more cleaved and altered, than the black shaly beds which have yielded the graptolites.[1]

In a paper read before the British Association at Southampton in 1882, Prof. W. Keeping states that he found some graptolites too badly preserved for precise identification in the cliff south of Pen Pistill, Newport Bay. Prof. Lapworth examined these, and stated that they might be Lower Llandovery, Llandeilo, or Arenig species of *Diplograptus* and *Climacograptus*. Judging from the lithological characters of the rocks, which are either pale-blue and grey felspathic grits—much less quartzose than the Aberystwith grits, and very ash-like in appearance—or else deep black slates occasionally ribboned with paler bands, Prof. W. Keeping thinks that they are of Llandeilo or Arenig age. Around Cardigan Harbour beds of precisely the same kind occur, and 'just beyond the little bridge over the stream at the south-western end of Cardigan town' in ashy-looking slates he found *Dicellograptus Morrisii* (Hopk.) and *Diplograptus socialis* (Lapw.), the former of which is a typical Bala fossil and occurs abundantly in the *Dicranograptus Clingani*- and *Pleurograptus linearis*-zones of the Hartfell Shales, while both forms are found associated in the Girvan area. Prof. Lapworth believes that, amongst the graptolites which Prof. W. Keeping sent him from the river Nevern, the Middle Bala form *Climacograptus tuberiferus* was the commonest, and that occurs well above the Bala Limestone. If the beds, therefore, are continuous westward across the Nevern valley towards Dinas and are not cut off by a fault, the age, at any rate of part, of these slates is fairly certain. But they seem from coast-sections to have suffered considerable folding, so that it would be more satisfactory to find definite fossil-evidence in the actual tract between Dinas and Newport.

It has been before stated that there are no volcanic beds intercalated in the great series of slates and shales which occur above the *Siphonotreta micula*-beds near Newport. The age of these sedimentaries has been fixed as Upper Llandeilo. But in Abereiddy Bay there are interbedded lavas and tuffs in the Upper Llandeilo; so that we seem here at Newport to have got outside the range of the volcanic eruptions of the later portion of this period. On the other side of Fishguard, however, there was extreme volcanic

[1] In some ashy flags outside the Castle, Newport, some crinoid stem-joints and obscure brachiopods have recently been found. These flags overlie the Upper Llandeilo graptolitic shales.

activity, if it be correct to assign the beds of Strumble Head to the Upper Llandeilo and Bala.

Unfortunately the slates there afford no fossil-evidence to settle the point; but, for the following stratigraphical reasons, the conclusion as to their age seems very probably correct:—

(i) The occurrence of definite Lower Llandeilo lavas, with underlying and overlying sedimentary rocks containing well-marked fossils, on the east side of Goodwick Bay.
(ii) The agreement in strike of both sets of beds.
(iii) The probability of the occupation of the intervening area of Goodwick Bay by Middle Llandeilo beds.
(iv) The soft, black, argillaceous shales of Feidr Pont Eglwys, near Pont Iago and Llanwnda, which break up into small splintery fragments, may very well correspond to the graptolitic shales of Newport and the lithologically similar beds of Abereiddy Bay.
(v) The agreement in position of the volcanic series and black shales with what we should expect from the effects of the Pwll Ceunant and Goodwick faults.

In the unfortunate absence of fossils from the slates and flags of Strumble Head there must at present remain a doubt as to their age; but the balance of evidence is in favour of the view that the Goodwick lavas and breccias are on the horizon of the great volcanic belt between Coch y Ceiliog (Pwll Ceunant) and Newport, and that the other volcanic rocks on Strumble Head are higher in the Bala series.

(*b*) The Contemporaneous Volcanic Rocks.

(1) *General Characters and Distribution.*

The age of the rocks has been already discussed, but a brief recapitulation of the conclusions arrived at will be useful. Firstly, the volcanic series that extends from Manorowen Hill through Cwm Bach, Bigney, across Fishguard Harbour to Castle Point is Lower Llandeilo. Secondly, the great volcanic belt that runs eastward from Coch y Ceiliog (by Pwll Ceunant) through Carn Fran, Bwlch Mawr, and Carn Ffoi to the Clydach valley belongs to the base of the Upper Llandeilo; and to this same horizon belongs the belt stretching inland in a south-westerly direction from the north-eastern extremity of Strumble Head past Goodwick and through Carn Gelli. Thirdly, the central outcrop of lavas and breccias north of the Garn Fawr–Y Garn intrusion is probably of Bala age, and is on a higher horizon than the Goodwick lavas. This central volcanic group of beds is cut obliquely to its strike by the Garn Fawr–Y Garn intrusion, but may be recognized also on the southern side of the diabase near Pwll Deri, where it has thinned out and split up into separate thin lava-flows and tuff-beds with interbedded slates, flags, and sandstones. The tendency of these three sets of

volcanic beds is thus to thin out to the south-west. Fourthly, the two small exposures of lavas and tuffs at Porth Sychan and Porth Melyn are slightly higher than the last mentioned.

Thus the volcanic outbursts are seen to have occurred in this area on approximatively the same horizons as those in Abereiddy Bay.[1] But they are less split up by interbedded slates, and are of greater thickness. For reasons which will be presently stated, we seem to be close to the site of the old vents.

The rough barren knolls and hillsides, with their white-weathered crust and scattered blocks on the surface, are marked features in the landscape. Each set of beds has some characters peculiar to itself in the field. Thus dark olive-green, brecciated lava-flows, and greenish lavas with conspicuous porphyritic felspars, are specially abundant between Carn Fran and Bwlch Mawr. Greyish lavas and coarse agglomerates, showing their pyroclastic nature in weathering, are rare on this horizon.

The Goodwick series, on the other hand, has breccias very strongly developed; and pale-greyish and dark bluish-grey lavas, banded or nodular, are highly characteristic. It is near the village of this name that proofs are furnished of the immediate vicinity of the ancient orifice of eruption. Indeed, it is not too much to say that we have here an old volcanic neck. On the foreshore and in the cliffs immediately below the Coastguard Station we find, let down between two faults against the banded and nodular lavas, a mass of exceedingly coarse breccia. Closely-packed angular blocks of all sizes from a few inches to a yard or more in diameter compose the beds which, tilted on end, run as parallel ridges, 4 to 8 feet high, along the beach. The blocks are confusedly heaped together, and are cemented by a fine ashy matrix. Huge fragments of the banded and nodular rhyolites of the cliff occur in these ridges, for the breccia is really of higher stratigraphical position than these lavas. At Penrhyn the maximum degree of coarseness is found, and there is very little fine ashy material to bind the blocks together. As the beds are traced along in the cliffs to the south-western corner of the bay, the number of large fragments rapidly decreases and the grey ashy matrix proportionately increases, until—at a distance of only about 50 yards from the point of maximum coarseness—an occasional fragment of banded rhyolite alone projects from the smooth vertical cleavage-faces of the grey ashy slates which form the cliff. In proportion as the fragments decrease, the cleavage of the grey tuff becomes more distinct and perfect. The actual channel up which the lava rose probably lies now to the north-east, below the sea, but cannot be far distant, as this coarse breccia must have accumulated round the lip of the orifice.

The second locality, in which we have plainer proof that we are on the site of an ancient 'neck,' is near the Caerlem farm, north of Garn Gilfach, on Strumble Head. Here a conspicuous, bare, rocky knoll stands out with steep rifted sides, 20 to 30 feet high, and

[1] Hicks, Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 177.

wholly composed of fragments of the greenish and grey lava-flows which crop out immediately to the east as far as 'North Pole' Cottage. A few pieces of black slate are seen in this coarse agglomerate of volcanic fragments, which is entirely different in composition from that exposed at Goodwick. We cannot doubt that we have here an old volcanic pipe, filled with the rocks shattered by the last explosions, similar to the pipes that are so common amongst the Upper Palæozoic rocks of Scotland.

The types of lava particularly noticeable at this horizon on Strumble Head are a pale greyish rock and a yellowish-green rock dotted with milk-white spots, and fragments of these compose the breccia.

The general appearance of most of the lavas in the field is flinty, with a more or less perfect conchoidal fracture. It is impossible to mention any constant features by which they can be distinguished from the finer compacted tuffs in the field, for they weather in a similar fashion, and even with the aid of the microscope the discrimination is frequently a matter of great difficulty and uncertainty. On a fresh fracture the lavas show considerable differences in colour, being in some cases pale grey, in others dark bluish-grey, in others again olive-green, and in yet others pale yellowish-green. They may all be included under the term 'felsite.' Their specific gravity ranges from 2·60 to 2·76.

There are three special types of structure remarkably well developed in some felsites of this area, all of which are visible to the naked eye in the field. Firstly, the banded structure is exhibited with great distinctness in many of the lava-beds near Goodwick: fine light and dark bands rapidly alternate one with the other, and sometimes are thrown into folds and convolutions. Secondly, there is the nodular structure. This has been found only at Penrhyn, near Goodwick, and the pale grey or whitish ovate nodules, $\frac{1}{2}$ inch or so in length, give a peculiar blotched or spotty appearance to the rock. They are frequently more or less fused together in strings, and either have their centre filled with a clear quartz-grain or are hollow. They weather out white in a dark-grey matrix, but the nodules compose the chief bulk of the rock. Weathered fragments and beach-pebbles of this peculiar lava bear a really striking resemblance to some species of the Carboniferous coral *Lithostrotion*. Thirdly, there is the perlitic structure. It is rare to find this macroscopically distinguishable, but on the weathered surface of the lavas of Carn Gelli, south-west of Goodwick, it is beautifully shown. Under the microscope slices of rocks from many other localities in this area show perlitic structure, as will be described farther on (pp. 172–73).

There are some rocks amongst the volcanic series which show a curious mottled, blotchy, or streaky appearance to the naked eye. In many cases, as in the rock from Carn Pica, between Fishguard and Dinas, it is practically certain that they are re-cemented lava-flows, in which the fragments of the brecciated crust or congealed

lava-stream have been more or less resorbed into a newer flow. The degree of consolidation, the composition of the fragments, the temperature and conditions of flow, etc., of the later lava-stream which involved them, have determined the extent of their re-fusion and manner of incorporation. Further details of these interesting rocks will be given in the description of their microscopic characters (see p. 176).

The only published description of any of the felsitic rocks from this area is found in Mr. F. Rutley's Survey Memoir on 'The Felsitic Lavas of England and Wales.'[1] Here he mentions a cryptocrystalline rock from Llanwnda with a banded flow-structure indicating a rhyolitic type. Another specimen, 'collected between the camp and the north coast' of Strumble Head, lacks the banding, and 'although there is no proof that it is a rhyolitic rock, its microscopic character .... shows that it consists of a meshwork or felting of delicate crystalline spiculæ, with apparently a little isotropic matter.' This is a bluish-grey flint-like rock, or hornstone.

With regard to the difficulty of distinguishing these rocks from altered slates and flags, Mr. Rutley in the same memoir goes so far as to say that 'it would, in fact, seem that we have passages from slates and flags into felsites, so that in the absence of any structural peculiarities it is scarcely possible to distinguish the one class of rocks from the other.' Clifton Ward held the same opinion, which seems, however, rather an exaggeration of difficulties.

Mr. Teall mentions in his 'British Petrography,' p. 336, that 'on the west side of Goodwick Bay, near Fishguard, there is a fine exposure of banded and brecciated felsites associated with felsitic agglomerates,' but he gives no further account of them.

(2) *Microscopic Characters of the Lavas.*

As we have to deal with a great diversity of types amidst the lavas (felsites) of this area, it may be useful to adopt some sort of classification, though it must be remembered that in nature there are no sharp divisional lines between the different types. A series of specimens might easily be selected in which every stage of transition would be represented. Teall ('Brit. Petrogr.' p. 308) roughly classifies the felsites; he says 'some felsites may be resolved into microcrystalline aggregates of definitely recognizable minerals (quartz and felspar or mica); others appear cryptocrystalline, and others again are isotropic, but without that entire absence of structure which distinguishes a glass. In addition to the above we find felsites which break up under crossed nicols into aggregates of double-refracting grains or patches, often of extreme irregularity, but of considerable size. The different varieties of felsite above referred to are intimately related to each other, and often co-exist in the same rock.' Teall has here followed the obvious plan of classification by the characters of the groundmass, and to a certain extent it may be conveniently adopted in this case.

[1] Mem. Geol. Surv. 1885, pp. 20, 21.

There is firstly the *cryptocrystalline* type. This is comparatively rare in a perfect and unassociated state, and it is not easy in all cases to determine amongst rocks of this class whether we are dealing with lava-flows or minutely comminuted silicified ashes, since both have the same hornstone-like appearance. The best examples of lavas with this type of groundmass occur in the neighbourhood of Goodwick. A rock of a very dark bluish-grey colour, which comes from the shore below that village, exhibits under the microscope numerous lath-shaped and squarish sections of felspar-crystals, granophyric aggregates of quartz and felspar, some probably of a porphyritic nature, others undoubtedly subsequent to the intratelluric period when the porphyritic felspars and quartz-crystals were formed, for some of the clear rounded quartz-crystals are surrounded by a secondary granophyric growth. Other small, rounded, clear grains of quartz are without this secondary ring, while others have corroded outlines; and there are the interesting micropegmatitic groups which are described immediately below. These features are exhibited in slides [76] and [21].[1]

The felspars usually belong to the potash series and monoclinic system, but in a rock from the road above Goodwick [67] a large number of the porphyritic elements show albite-twinning.

The micropegmatitic structures are especially striking in some of these rocks [21], [42], [76] (Pl. VI. figs. 3, 4, 5). Their peculiar appearance at once catches the eye. From a central or subcentral point in a clear, crystalline, definitely circumscribed patch, blunt, reticulating, and branched processes radiate outwards in all directions towards the bounding-faces of the crystal or borders of the crystal-group. Sometimes these clear patches have the outlines of felspar and at other times of quartz-crystals; but usually they are more or less irregular in shape. They are clearly marked off from the cryptocrystalline groundmass. Under crossed nicols they are seen to consist either of a single individual crystal containing the radiating processes, or more commonly of a group of a few crystalline grains, differently orientated, irregularly aggregated, and penetrated indifferently by the same processes.[2] In fact, Prof. Judd's term 'glomero-porphyritic' might be suitably applied to these groups; and the appellation 'glomero-porphyritic micropegmatite' has been suggested to me by Mr. H. Kynaston, F.G.S., who has found similar structures in some Cheviot quartz-porphyries. They are undoubtedly original structures, and belong to the same period of formation as the porphyritic felspars. A granophyric group is described by Iddings[3] in a rhyolite from Eureka, Nevada, which is very similar to the Goodwick structures: and Mr. H. Woods, F.G.S., has shown me a slide from a Builth rock of Ordovician age with the same

[1] In this paper the numbers in square brackets are those of the microscope-slides in the Woodwardian Museum.

[2] In the lava-fragments contained in one of the Goodwick breccias [27] these structures are of unusual beauty.

[3] Seventh Annual Report (1886), U.S. Geol. Surv., 'Obsidian Cliff, Yellowstone Park,' p. 275.

centric structures. Prof. Judd's figure of the quartz and micropegmatite groups in the granite-nucleus of a spherulite from the Cuillin Hills [1] shows similar features.

The cryptocrystalline type of groundmass is co-existent with another type—the microlitic (which will be subsequently described) —in a rock from Carn Gelli [203] amongst others. This rock in the field has a pale greenish-grey, mottled appearance, and conchoidal fracture, and under the microscope shows very numerous scattered microlites embedded in a cryptocrystalline base. In this also lie large, porphyritic, Carlsbad-twinned felspar-crystals, with their angles rounded off as if corroded by the magma in which they floated. Some local rise of temperature, or increase either of pressure or in the quantity of water, has affected the stability of the molecules of the crystal and produced this exterior corrosion.[2] The greenish colour of the rock is due to the swarms of minute, pale-green granules or globulites. In many parts of this rock beautiful perlitic structure occurs, and is brought out conspicuously also by the action of weathering. The general appearance and mineralogical composition of this Carn Gelli rock indicate a lower percentage of silica than in the Goodwick lavas, and it may reasonably be placed among the trachytoid felsites.

The occurrence of perlitic structures among these rocks is not uncommon. A good example is seen in a rock from Crincoed [4], where also fluxion-structure is plainly indicated by the lines of parallel microlites. Lines of flow are also beautifully shown, bending round felspar-crystals in a rock from Carn Blewyn, near Llanllawer [322], [325], in a cryptocrystalline groundmass.

In all the foregoing cases devitrification of the groundmass has occurred. Whether this devitrification took place at the time of solidification or subsequent to it cannot be affirmed with certainty; but I am inclined to think that we have here to do with subsequent (secondary) devitrification, on account of the close association with and passage into rocks which undoubtedly consolidated as glasses (obsidians or pitchstones), as the presence of perlitic structure indicates.

Here may be mentioned two striking varieties of the felsites possessing a cryptocrystalline base. The first variety is characterized by banding, and is well shown in the immediate vicinity of Goodwick, as previously described. Under the microscope [86] the dark bands show numerous granules and minute crystals of magnetite and a greenish-grey semi-opaque substance which is not distinguishable from the cryptocrystalline matrix with crossed nicols. In the light bands these elements are absent. The 'glomero-porphyritic' groups of micropegmatite, similar to those previously described, are present, and small porphyritic lath-shaped felspars with lamellar twinning and orthoclase-crystals are also fairly common. Portions of the groundmass have become microcrystalline. The banding is

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 189.
[2] Bonney, Pres. Addr., Quart. Journ. Geol. Soc. vol. xli. (1885) *Proc.* p. 80.

plainly an original flow-structure, and is not due to such belts of minute spherulites as are the cause of similar macroscopic features in some felsites. The specific gravity of this rock is 2·60.

The second variety is conspicuous on account of the occurrence in it of small nodules, which measure $\frac{1}{2}$ inch or more in length, and show as white oval patches on a fresh surface (see above, p. 160). This variety is found only in the cliffs under Goodwick village and on the slopes of the hill behind it. The nodular structure does not appear to mark a special bed of lava, but to be locally developed in the ordinary banded felsite of these cliffs. A few scattered nodules first occur, and these rapidly increase in numbers to the maximum when they constitute the bulk of the rock. There is no reason to think that these nodules are of secondary origin. A study of them under the microscope supports the idea that they are rather of concretionary origin. But the word 'concretionary' is so associated with the thought of attractive centripetal force that it is misleading here, since a centrifugal force seems to have been at work driving away from definite centres the colouring-matter of the matrix in a manner analogous to that in the formation of 'spots' in slates undergoing contact-metamorphism. A slight difference in composition—probably a higher percentage of silica—is indicated by the greater resistance to weathering offered by the nodules, so that they project as rough lumps on an exposed surface. Under the microscope this rock [21] shows numerous small lath-shaped felspars, with lamellar twinning, scattered through the groundmass, and irregular micropegmatitic groups of the types already described. Ovoid aggregates of clear quartz-grains mark the centre of many of the nodules, which are more transparent than the other parts of the rock and freer from porphyritic crystals. They are also devoid of the streaky flow-structure of the groundmass. The specific gravity of this rock is 2·62.

The second type of groundmass may be called the *microlitic*, and represents the ordinary trachytic groundmass of rhyolites and trachytes. These rocks are less acid, owing to the absence of large porphyritic quartz-crystals.

The groundmass is composed of a felt of microlites, of several degrees of fineness and corresponding to Rutley's 'spiculæ.' In some cases they seem roughly orientated into groups, or cross at right angles; but generally they are densely interlaced without any order.

The rocks in which the best examples of this type of groundmass occur commonly contain large porphyritic felspars—a distinctly intratelluric generation—usually of orthoclase with corroded angles, but occasionally of plagioclase with albite-twinning. Good examples of this microlitic type are found on Carn Fran [104], [100], [201], [45], and on Carn Ffoi near Newport [312], [338]. In the last two slides the felt is composed of extremely fine microlites, and the triclinic felspars belong to the oligoclase-albite series.

The microlitic type is so generally associated with the third type

of groundmass that it is difficult to find even one slide in which the two do not co-exist. This third type is the *micropoikilitic*. The name is applied to that 'blurred-mosaic' groundmass which is the commonest condition in the lavas of this area. For many reasons, which will be adduced later, it appears not to be an original structure, but of secondary origin, subsequent to the consolidation of the rock, and even in some cases later than the development of the cryptocrystalline or felsitic condition. It is of special interest and significance to find here traces of a change having taken place *after* the rocks had suffered devitrification. However, I am inclined to ascribe it to contact-metamorphism produced by the numerous sheets of intrusive material and laccolites in the neighbourhood.[1]

The name 'micropoikilitic,' in the first place, needs some explanation. The author of the name 'pœcilitic,' as applied to a minute rock-structure, is Prof. E. Haworth, who in 1888 first used it for a new type of structure of the groundmass in the porphyries of Missouri.[2] He refers in this paper to an analogous structure in some coarse-grained peridotites described by Prof. G. H. Williams,[3] in which large hornblende-crystals contain grains of olivine and hypersthene. The latter author considers it to be a distinct type of the holocrystalline groundmass.

Haworth, in describing the quartz-porphyries of Missouri, says:— 'In many of the fine-grained rocks the individual grains cannot be seen unless highly magnified, but if the section be revolved on the stage of the microscope while the nicols are crossed the whole field is broken up into different areas, each of which will change alternately from dark to light. A great many little specks of felspathic material are scattered through the whole mass, but they seem to be entirely irregular in their arrangement. . . . . As the crystallization increases these different areas increase in definiteness, so that in the more coarse-grained varieties their true character can readily be determined.' Some of the areas have central quartz-crystals with a large surrounding portion of quartz in similar optical orientation, but irregularly spotted over with felspathic material. Other areas have no central crystal, but consist of a quartz groundmass with the felspathic material irregularly distributed over the whole of it. 'In some cases the felspar is well crystallized, and projects into the quartz-crystal.' The definiteness and individualization of each area depend on the degree of crystallization. Prof. Haworth considers this 'pœcilitic' structure to be original, and he has traced a whole series of transitional stages from rocks with a microgranitic to rocks with a vitrophyric structure,

[1] This view of the origin of this structure has been recently adopted by Mr. Harker (Quart. Journ. Geol. Soc. vol. l. 1894, p. 333) in the case of the fragments of Eycott lavas included in the Carrock Fell gabbro. I had independently formed the same view several months before Mr. Harker's paper appeared.

[2] 'On the Archæan Geology of Missouri,' pt. ii. 'American Geologist,' vol. i. (1888) p. 367 and pl. i. figs. 1, 3.

[3] 'The Peridotites of the Cortlandt Series,' Amer. Journ. Sci. ser. 3, vol. xxxi. (1886) p. 30, and 'The Norites of the Cortlandt Series,' vol. xxxiii. (1887) p. 139.

the differences, in his opinion, being largely brought about by the varying depths at which portions of the original magma consolidated. Though I cannot hold that his interpretation applies to the lava-flows in the Fishguard area, yet I have referred to his paper at some length since it contains the first minute account and figures of this type of structure in acid igneous rocks, and recognizes its distinct character. Teall mentions a similar structure in a quartz-felsite from the Cheviots, but not under this name.[1] Iddings describes it in certain dyke-porphyrites in the Yellowstone Park,[2] and G. H. Williams states that it is well developed in acid lavas on South Mountain, in Southern Pennsylvania and Maryland.[3] Recently referring[4] to these, the latter writer says:—'It can there be proved in some cases to be of secondary origin, as it occurs in plainly devitrified glasses, and it is the writer's opinion that such enclosing quartz-areas will, in many cases, prove to have originated subsequent to the solidification of the rock.' The same author here also defines the meaning of the terms 'poikilitic' and 'micropoikilitic' as 'rock-structures, whether primary or secondary, conditioned by comparatively large individuals of one mineral enveloping smaller individuals of other minerals, which have no regular arrangement in respect either to one another or to their host.'

Rutley describes a Builth rock which under the microscope 'breaks up into a series of irregularly rounded and angular patches when rotated between crossed nicols'[5]; and, in the devitrified glassy rocks of the Glyders and Snowdon, there are mentioned large irregular patches with uniform extinction but badly defined boundaries under crossed nicols. Hatch[6], at the last Newcastle meeting of the British Association, in speaking of two Wicklow soda-felsites, mentions a 'patchy devitrification' in one case, and in the other 'a tendency of the groundmass to depolarize in patches.'

Teall, on p. 308 of his 'British Petrography,' speaks of 'aggregates of double-refracting grains or patches, often of extreme irregularity, but of considerable size,' occurring in some felsites and rendered visible only with crossed nicols.

The above-mentioned authors all apparently refer to this same structure—now conveniently designated 'micropoikilitic.' In the Fishguard rocks it constitutes a blurred or a definite mosaic of quartz-patches, pervading the whole rock or merely portions of it, or even only parts of a microscope-slide. The patches, which behave as single crystal-individuals, may form a connected mosaic of coarse or fine grain; or they may occur more or less isolated from each other, with a groundmass of the cryptocrystalline or microlitic type intervening between them. Each patch may be definitely marked off from its neighbours, and in this case the mosaic is generally

[1] 'British Petrography,' 1888, p. 343.
[2] Twelfth Annual Report U.S. Geol. Surv. 1891, p. 589.
[3] Amer. Journ. Sci. ser. 3, vol. xliv. (1892) p. 482.
[4] 'Journal of Geology,' Chicago, vol. i. (1893) p. 179.
[5] 'Felsitic Lavas of England and Wales,' Mem. Geol. Surv. (1885) p. 21.
[6] Rep. Brit. Assoc. (1889) p. 568, and Geol. Mag. 1889, p. 547.

coarse and freer from 'dusty' material; or the patches may be indistinctly blended with each other, so as to give a blurred appearance with crossed nicols. In some cases, the inclusions in the patches consist entirely of microlites; in others, principally of felsitic, cryptocrystalline, or 'dusty' material; and in yet other cases, of a mixture of these two kinds.

It has been stated that the simple typical cryptocrystalline and microlitic groundmass may co-exist even in the same microscope-slide with the micropoikilitic structure; and perlitic structure may also occasionally be found with it, though in the coarser mosaics the perlitic cracks tend to become effaced or very indistinct.

It has been seen that it is the opinion of the majority of observers that the structure is secondary, and a form of devitrification. From the following considerations I am inclined to think that it is developed subsequent to the ordinary devitrification of an acid lava with a glassy base; or at any rate later than the production of the felsitic matter which one is accustomed to regard as the normal result of devitrification.

In the first place, we have seen that the cryptocrystalline and microlitic types of groundmass may exist side by side in the same rock, pointing to the original occurrence of patches of glassy material in the midst of a rock in which crystallization was just commencing. Holding the formation of microlites to be the first stage in the building up of crystals, we may look upon these patches of interlacing microlites in the midst of a glassy base as so many centres of incipient crystallization. At this stage the rock consolidated; and then the glassy patches suffered the well-known change by which they became felsitic or cryptocrystalline, or, in common parlance, they were 'devitrified'; and one gets a rock such as that from Carn Gelli [203] previously described.

In the next place we find rocks either with a simple microlitic or a simple cryptocrystalline groundmass, or with a microlitic-cryptocrystalline groundmass, with only small patches of the micropoikilitic structure scattered about in it. These sporadic patches, each behaving as a single crystalline individual, and generally with a blurred indefinite boundary, contain the microlites, etc., of the rest of the rock, while between the patches the groundmass exists unaltered. Examples of this condition in felsites with microlitic groundmass are found in slides [202], [209], [231], [70], and [318], from such widely separated localities and horizons as Carn Fran, Carn Gelli, and Strumble Head. Well-marked perlitic and flow-structures are seen in those in which the 'micropoikilitization' is only slight [5]. Among cryptocrystalline felsites this first stage is exhibited in some rocks from the neighbourhood of Goodwick [69], [34]; and in a rock from Carn Gelli [96] there is very good perlitic structure preserved in an almost simple cryptocrystalline base.

The next stage shows the micropoikilitic structure more generally and regularly distributed throughout the rock. An example of this stage is a banded cryptocrystalline felsite from near Goodwick

[52]. In this rock the material included in the mosaic patches is therefore of a felsitic nature. (The rock also exhibits the direction of flow by the parallel position of its felspar-crystals, some of which have corroded angles.) Another example is [74], in which the orthoclase-crystals show a zone of second growth; and in another case [6] microlites abound in the cryptocrystalline base.

Of microlitic felsites in which this stage of 'micropoikilitization' is shown there are very numerous instances from all parts of the area examined,—Carn Gelli, Cwm Brandy, Goodwick, Strumble Head, Carn Llys, near St. Nicholas, etc. [91], [92], [245], [61], [215], [210], [212], [213], [26], [329], and [324]. In the case of two from Carn Gelli [91], [92], perlitic structure is beautifully shown; and the two slides prepared from a rock from Carn Llys [329], [324] are remarkable for having no porphyritic felspars—a very unusual condition in microlitic felsites from this area.

A further stage, in which the mosaic is very well and completely developed throughout, is seen in some rocks from Strumble Head and elsewhere.

In many cases the inclusions consist of the microlites of the original groundmass [238], [254], [223], [2]; and in [87] perlitic structure is visible.

Amongst felsites with cryptocrystalline inclusions in the micropoikilitic mosaic may be mentioned [229] with large porphyritic crystals, and [256], [246] from Strumble Head.

The most complete 'micropoikilitization' is shown in a rock from Bigney [208], [221], and in another from Carn Llys [347].

In some cases a slightly different type occurs; patches of clear quartz containing no inclusions are scattered about in the midst of a microlitic or cryptocrystalline groundmass [207]. Perhaps the peculiar rock from the neighbourhood of Carn Gelli [210], in which the groundmass appears to consist of true micropegmatite with blurred and indistinct small felspar-crystals and microlites lying in it, may be related to the true micropoikilitic type.

But, putting aside these two last-mentioned exceptional and aberrant types, we see that it is possible to trace without difficulty a series of stages in the development of the micropoikilitic structure from rocks with a simple microlitic or cryptocrystalline groundmass. The first stage in its development exhibits disconnected small patches occupying only a small proportion of the whole rock; the next stage shows them more closely aggregated and usurping the greater part of the rock; in the third stage they pervade the whole substance of the rock, but still have somewhat indistinct boundaries and are of small size; and in the last stage they form coarse mosaic, with the individual patches clearly defined. Haworth, in his previously quoted account of this structure, though considering it original and a type of the holocrystalline structure, yet expresses the opinion that this coarse, clearly defined mosaic is its most perfect and complete development, thus arriving at the same conclusion, though on different lines.

The next fact to be taken into consideration in connexion with

this structure is that the rocks contain veins of secondary quartz, second growths of quartz round earlier formed grains, vesicles infilled with quartz, felspars replaced by quartz [330], and similar evidence of the infiltration and addition of silica since the solidifying of the rocks. Again, the associated tuffs and breccias are for the most part silicified and have assumed a flinty texture, while some rocks which almost certainly are tuffs show some indication of micropoikilitization. Therefore the evidence on the whole might seem to point to a kind of silicification, possibly brought about by solfataric action, as suggested by Miss C. A. Raisin for certain rocks from North Wales.

But a most suggestive paper by Mr. W. M. Hutchings in the Geological Magazine for February, 1894, p. 64, draws attention to the development of a fine mosaic or 'tesselated' structure as a result of contact-metamorphism in slates. It is possible, or rather probable, that we have in these felsites an analogous case: the conditions for contact-metamorphism are most favourable, masses of intrusive diabase, etc., being present in abundance.

Mr. Hutchings puts forward the view that a kind of solution of minerals must have been formed by a process resembling aqueous fusion. The presence of heat, pressure, and a certain amount of water is necessary, judging from laboratory experiments, but these were undoubtedly present in nature; and the highly acid groundmass of these old rhyolitic lavas, whether in a cryptocrystalline or glassy condition, produced a solution in which floated the less easily attacked microlites, granules, etc., of the original rock. On the cooling of the mass the solution crystallized as a blurred aggregate of quartz and felspar, forming a kind of granophyric structure —the blurred mosaic. In cases in which the quartz and felspar separate out from each other more completely, or in which the solution is almost of pure silica (as would be likely in the highly acid magma of the rhyolites forming the original undifferentiated or glassy base), the mosaic is less blurred, and each patch is more definitely marked out. When the solution of the groundmass was only in its infancy, merely small portions of the rock were affected, and if the necessary conditions for the metamorphism were abruptly removed at this stage, the rock would re-solidify so as to exhibit a few blurred, scattered patches of the mosaic. A similar incomplete development of the mosaic may be due to the penetration of rocks, far removed from the contact-area, by tongues of the highly heated acid and corrosive solution in its migration from its original home. But I am not inclined to think that there was much, if any, lateral transference of material or migration of solution from its place of formation; otherwise the preservation of original structures, such as the perlitic, and the absence of superinduced flow-structure would be difficult to explain. If Mr. Hutchings's theory of solution be the true explanation of the mosaic structure in the felsites, the solution must have consolidated in its original home; there can have been no lateral or horizontal flow; and the rate and local conditions of cooling, and the composition and structure of the rock, etc., must have been the

forces that determined the ultimate character and degree of perfection of the micropoikilitic structure.

With regard to the field-evidence, the size and nearness of the intrusive masses seem connected with the degree of development of this structure, the most perfect and complete examples of coarse mosaic being found nearest the largest masses of diabase. An instance of this is the Strumble Head set of felsites. Not a little seems to depend on the original nature of the rock, as might be expected. The existence of intrusive masses concealed underground may account for cases otherwise difficult to explain.

I would still ascribe the infilling of the vesicles and veins with quartz to a different and subsequent process; the abundance of secondary quartz (see p. 183) in some of the diabases lends support to this view. The sort of solution that caused this infilling must have been in a very different state from the highly heated one which produced the micropoikilitic structure. On the whole I think we may regard the latter structure as a result, at any rate in many cases, of contact-metamorphism.

Mr. Hutchings (Geol. Mag. 1894) mentions the occurrence of this structure, which he calls the 'tesselated or mosaic structure,' in certain altered andesitic and rhyolitic ashes in the contact-zone of the Shap granite, and says that it is by no means peculiar to the alteration of sedimentary rocks.

A rhyolitic tuff [58] which is in contact with a mass of diabase on Fishguard Quay (on the western side of the harbour) exhibits the micropoikilitic structure well developed. This is an important confirmation of the previously expressed views.

The same author further reminds us that Lieut.-Gen. McMahon described a similar structure on the margin of the Dartmoor granite,[1] and previously in granite of the Himalayas. In the groundmass of certain quartz-porphyries it is well known,[2] and Mr. Hutchings says that there it is indistinguishable from the finer mosaic of slates, except by the characters of the inclusions. On Castle Point, Fishguard, it is difficult to say whether a rock [68] in which a small patched mosaic is developed was originally a fine tuff or a lava-flow, but the general character of the inclusions leads one to consider it a tuff.

The somewhat erratic manner in which the mosaic structure is developed may be explained, as the same writer suggests, by the irregular contour of the intrusion below ground, and also by the varying degrees of susceptibility of the more or less different rocks.

Naturally one would have liked to trace the series of stages of its development in one continuous bed of lava. But the nature of the ground and the variability of each lava-flow did not allow of this being done in any case with which I met. In the absence, therefore, of definite field-evidence of this kind I must leave it, at any rate for the present, an undecided question whether Mr. Hutchings's expla-

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 388.
[2] Haworth, 'American Geologist,' vol. i. (1888) p. 363.

nation applies to the micropoikilitic rocks in this area. The balance of evidence appears to me to be in favour of its applicability.[1]

The microcrystalline condition of the groundmass of some felsites [285], [205], [206], [344] is another type of alteration. In some cases the porphyritic felspars are obliterated; in others they remain distinct, at least in the early stages of the development of the microcrystalline aggregate [206]. The boundaries of the individual grains are fairly distinct.

Slight local variations of the groundmass, probably due to original differences in texture and composition influencing the mode of devitrification and secondary replacement, are noticeable in a few cases. Thus a rock from Trefelgarn [217] has parts of the groundmass microlitic, and other parts microcrystalline and spherulitic.

In a very vesicular rock from Cnwc Mawr [305], we meet with a spherulitic type of devitrification in the groundmass. The spherulites show an indistinct black cross with crossed nicols, but have no definite outlines and merge insensibly into the rest of the groundmass. Some have been formed round a quartz-grain at the centre. 'Pseudo-spherulites' would be, I think, a better designation than spherulites proper. In other cases, where the microcrystalline condition is strongly and most completely developed, it is difficult to know the original nature of the rock or to decide whether it is of pyroclastic origin or not; take, for instance [285].

There are a few rocks from the tract just north of Carn Ffoi, near Newport, which, though undoubtedly felsites, show some uncommon features. When viewed under the microscope they [315], [334], [335], [340] all at first sight have the appearance of vesicular rhyolites. The groundmass may be either cryptocrystalline, microcrystalline, or micropoikilitic, and varies considerably in each section. There are a number of clear spots scattered about in it; some are circular, others are oval, others are irregular in shape, but nearly all are bordered by a line of dark green granules which form a definite encircling ring. The clear central portion sometimes shows radial structure, and gives a more or less distinct black cross with crossed nicols; but in other cases the interior is cryptocrystalline, or behaves like a patch of the blurred mosaic in micropoikilitic felsites.

The green granules that surround the clear spots may be also seen scattered sparingly through the rest of the rock, in addition to grains, flecks, and shreds of the same colour. In some cases the green ring round a spot is broken and irregular, or it may be entirely absent. But when present it is invariably narrow, and looks merely like a green line. Large porphyritic felspars with low extinction-angles occur in some of the sections: [315], [340].

[1] The foregoing conclusions, which were written out some months before the appearance of Mr. Harker's first paper on Carrock Fell (Quart. Journ. Geol. Soc. vol. l. 1894, p. 311), are supported by his observations on the metamorphism of the surrounding lavas and the development of micropoikilitic structure by the intrusive gabbro.

Small, well-formed felspar-crystals project into the spots from the groundmass, or lie wholly inside them [315]. I have been unable to decide whether these spots are original or secondary structures; but the evidence seems rather to indicate that they are original cavities subsequently filled in with silica, or the silica may pseudomorph some pre-existing mineral. Mr. Harker describes an apparently similar type of structure common in the lowest Bala lavas at Y Drosgl, near Dwygyfylchi, and at Penmaenbach and elsewhere.[1] In these rocks circular, elliptic, or irregularly shaped spots occur, marked out by a dusty-looking border. Within each spot the quartz and felspar are more or less completely individualized, the former being in excess of the latter, and the whole of the quartz behaves as a single crystal. Mr. Harker was inclined to think these structures original, but is somewhat doubtful on this point in the case of some Cross Fell rhyolitic rocks.[2]

Reference has frequently been made in this paper to perlitic rocks. But there are some occurring near Bwlch Mawr, Dinas, which are of especial interest. In one case [316] (Pl. VI. fig. 1) the perlitic structure occurs in narrow bands, suggesting the outpouring of successive thin streams of lava, in each of which the outer surface cooled rapidly into a glass. The perlitic structure is marvellously preserved, and the large curving cracks surrounding spheroidal portions of the groundmass frequently enclose smaller concentric curves, or nests of smaller spheroids in minute imitation of the spheroidal structure in diabase-masses described and figured by Prof. Bonney.[3] In some of the areas within the perlitic curves there are seen in ordinary light under the microscope a dozen or more small, clear, circular spots either isolated from each other or collected in groups which have a reticulate appearance and fill up the whole of the enclosed space. Each minute spot has in the majority of cases a dark dot at its centre. In that portion of the rock less replaced by quartz-mosaic and with the best-preserved perlitic structure these minute spheres are regular, and have well-defined boundaries. Each behaves as a single crystalline individual of quartz. In more altered portions they are irregular in outline and run one into the other in a more or less confused manner. In some cases radially arranged inclusions of very fine dusty material or crystallites occur in them, but no true spherulitic structure is observable. Where a considerable number are crowded together so as to assume polygonal outlines, a reticulate appearance is produced, and this seems to be that structure compared by Miss Raisin to crackled china in a felstone from the Lleyn, in which 'the groundmass shows perlitic curves, and appears also minutely broken, like crackled china.'[4] This resemblance to crackled china is particu-

[1] 'The Bala Volcanic Series of Caernarvonshire' (Sedgwick Essay), 1889, p. 22.

[2] Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 519.

[3] *Ibid.* vol. xxxii. (1876) p. 151.

[4] 'Nodular Felstones of the Lleyn,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 251.

larly marked where the centres of the meshes of the network have no central dark dot. In cases of extreme silicification and recrystallization these minute spheres have fused together and produced crystalline patches of quartz extinguishing simultaneously, but the centres and occasionally the outlines or the positions of the separate spheres may in a few cases be detected by means of the persistent radial inclusions. (Pl. VI. fig. 1.)

The original groundmass is of a pale greenish or pale brownish colour, and is isotropic or felsitic. The secondary quartz-mosaic (not micropoikilitic) varies in irregularity of grain with the degree of alteration. The perlitic and other structures, plainly shown in some sections [316], [319], are scarcely discernible where the alteration into the mosaic is extreme [320].

With regard to the origin of the 'minute spheres,' I think we must regard them as simply very minute spheroidal structures produced at the same time as the larger spheroido-perlitic structure, for they graduate insensibly, when clustered together, into the 'crackled china' structure. Moreover, they tend to be obliterated by the replacement of the rock by the quartz-mosaic aggregate. It does not seem possible to regard them as spherulites of any kind, though it must be granted that their origin is at present obscure.

Another rock from the same locality—Bwlch Mawr—shows an entirely different method of replacement, and, judging from its peculiar features, was most probably a perlite with lithophysæ. In a section of it [83] we see irregular curving shreds and bands of clear quartz; sometimes a long, curved, jagged-edged band behaves as a single crystal with crossed nicols. But in ordinary light perlitic structure can be seen, being indicated by the more transparent curving bands and lines of quartz. The abrupt way in which these bands terminate, and their more or less sporadic and disconnected manner of occurrence, point to a shattering of the rock after the formation of the lithophysæ and perlitic curves, and an irregular opening of these cracks at the same time into which silica infiltrated, subsequently cementing the rock together again. In relation to these quartz-bands or infilled cracks, or quite independent of them, are circular or oval patches of cryptocrystalline silica which I hold occupy the original lithophysal cavities. In places these patches seem to consist of a minute micropegmatite or of a microcrystalline aggregate. They are frequently encircled by the curving quartz-bands. The patches may show a faint radial structure, but are not definitely recognizable pseudo-spherulites or incipient true spherulites. Patches and angular grains or groups of grains of clear quartz abound; and lines of minute greenish granules sometimes help to define the perlitic cracks.

All the peculiar features of this rock seem explicable on the assumption of a primary shattering, followed by complete replacement by cryptocrystalline and crystalline silica.

In many of the felsites of this area vesicles are prominent features, and are of interest as showing both the primary and

secondary origin of amygdaloids. Simple infilled original vesicles are common, and are usually represented as quartz-amygdaloids. As an example may be taken a rock [231] from the volcanic series on Strumble Head, north of Garn Gilfach. In this there are numerous oval or lenticular patches of clear quartz-grains with some included epidote. By their regular shape and the parallelism of their longer axes they must be considered as original vesicles drawn out in the direction of flow, and subsequently infilled with quartz. Minute granules of a pale greenish colour abound in the rock.

Beautiful instances of this well-known type are found also on Carn Madog and Carn Ffoi. Sometimes the outer lining of the vesicles consists of radially arranged quartz-fibres, while the interior is filled with clear quartz-grains [305]. But these are not of the nature of hollow spherulites (lithophysæ). Incipient spherulites of true secondary origin occur in the groundmass of the same rock. The centre of a vesicle may be occupied by epidote, while the rest of it is filled with quartz [245].

An interesting rock from the vicinity of Caerlem, on Strumble Head, shows oval white patches dotted about in a pale yellowish-green matrix [232]. Under the microscope the spherulitic type of devitrification, described by Rutley in the Long Sleddale rock,[1] is found accompanying the micropoikilitic structure. The latter is only partially developed, patches of the cryptocrystalline groundmass and microlitic felt being still present. The spherulites, each giving a distinct black cross, occur in ovoid or irregular patches and constitute the oval opaque white spots. These spots seem to represent original true vesicles, each of which is the centre of the special type of devitrification which has obscured their outlines.

In one of the micropoikilitic felsites [6] from the neighbourhood of Ciliau, east of Llanwnda, the vesicles are lined with a very pale green, transparent, granular, isotropic mineral; the centre of each is occupied by one or more crystalline patches of quartz, and one or more well-formed and perfectly terminated twinned felspar-crystals are seen in the interior of several vesicles. These felspars must be of secondary origin, but are earlier than the quartz-infilling. In this case I do not believe that the vesicles, with their irregular outlines, can be original gas-filled cavities. It seems more probable that these have been either decomposition-cavities subsequently filled up by quartz, or that they are segregatory patches due to a differentiation of the rock, before its final consolidation or at the time of its micropoikilitization.

'Contraction-spheroids' are represented in a rock from Caerlem [238], in which the groundmass has suffered partial micropoikilitization. In ordinary light one notices under the microscope oval or irregularly-shaped areas, distinguished by their pale brownish colour and abundant specks of an opaque or dark greenish dust. A clearer irregular central patch is visible in all; and the whole

[1] 'Felsitic Lavas of England and Wales,' p. 12 & pl. ii. fig. 1.

brownish area is in some cases marked off from the matrix by concentric cracks. With crossed nicols these areas are seen to contain fewer microlites and less felsitic matter than the surrounding groundmass, and the central clear mass is seen to consist of mammillated chalcedony. This rock, therefore, is a type of nodular felsite, resembling some of those from the Lleyn peninsula. Its specific gravity is 2·66.

(*c*) The Pyroclastic Rocks.

Fine tuffs containing fragments of the cryptocrystalline and microlitic types of felsites are fairly common. They have almost invariably been indurated or re-cemented by a secondary deposit of silica, and are tough, fine-grained, and flinty in appearance, so that in the field it is difficult to distinguish them from the true lava-beds. Clifton Ward states that the highly altered Arenig and Snowdonian ashes are indistinguishable, even under the microscope, from felstones.

The principal horizons for pyroclastic rocks are at the base and top of each volcanic series; but they are very locally distributed. Thus at the top of the lava-beds near Newport grey ashes come in, to a thickness of 50 feet or more along the Cilgwyn road, while they are absent or very feebly developed near Carn Pica; and near Bwlch Mawr, Carn Fron, and Coch y Ceiliog they have very different characters. Nowhere east of Fishguard are they so coarse as at Goodwick. But there are fine tuffs among the coarse breccias between Goodwick and Pen Anglas [27], [7].

The tuffs that are found on Castle and Saddle Points, on the sides of Fishguard Harbour, belong to the top of the lowest set of volcanic beds in this district; they have a dark-grey colour, and white crystals of felspar are scattered about in them, the hand-specimens reminding one of some of the Arenig 'porphyries' of North Wales [211], [37], [75], [220], [48], and [103]. Some of the sections look so much like lavas that it was only after a study of a large series of slides from these rocks that I was convinced of their clastic origin. On the same strike are the Cwm Bach tuffs [204], [214], and [284] with very similar characters.

Some interesting ashes composed of fragments of highly vesicular lavas, lapilli, etc., occur on both sides of Fishguard Harbour, but are especially well shown on the west side. They have in the field an entirely different appearance from any others met with in this area, being strongly cleaved and of a greenish-grey, bluish-grey, or purplish colour. Many bear, at the first glance, a great resemblance to crushed diabases. But under the microscope their true origin is apparent, though they contain a large amount of secondary minerals—calcite, dolomite, etc. Some of the carbonates may be original, for these tuffs accumulated on the sea-floor. One section [98] consists not only of fragments of vesicular lavas, but also of slates, quartz-mosaics, microcrystalline lavas, broken felspar- and

quartz-crystals in a decomposed, brownish, almost isotropic matrix. The majority are composed almost entirely of very vesicular fragments; the vesicles are filled with calcite or dolomite, and the former exists also in large crystalline plates in the matrix [16], [29], [51], [14], and [105].

Another rock resembles a fine-grained bluish-grey slate [68], but under the microscope it is seen to consist of a microcrystalline to isotropic groundmass with vesicular fragments embedded in it. Another similar rock [80] has the appearance of a fine-bedded cleaved slaty ash. Black chloritoid flakes have been developed along the cleavage-planes in some cases [99] by the crushing.

The tuffs to the north of Carn Fran, on the road to Dinas, have the greenish colour of the lavas of whose fragments they are composed, due to the presence of multitudes of small greenish granules. Near Pwll Deri thin interbedded tuffs occur [102], being the lateral modification of the coarse breccias of Caerlem. Again, at Porth Sychan tuffs occur. The coarse breccias of Goodwick and Caerlem have already been described (p. 159).

Many of the rocks show their fragmental origin much more clearly in weathered hand-specimens than under the microscope. But still a large number, having suffered almost complete replacement of their groundmass and inclusions by quartz, must remain doubtful [255], [244], [239], and [284].

Several, however, of these apparently fragmental rocks, or whose original character it is difficult to decide, are probably contemporaneously brecciated lava-streams—broken up and re-cemented coulées. They have a peculiar streaky look, or show included angular fragments. The rocks, too, are more compact and homogeneous than, as a rule, are those composed entirely of pyroclastic materials.

Such rocks are found between Bwlch Mawr and Fishguard, especially around and on Carn Pica [248], [236], and [260]. The process of their formation must have been somewhat as follows:—The solidified crust of the lava-stream was broken up and shattered by a suddenly increased rapidity of flow or tension due to a fresh outpouring of lava; the fragments of the crust sank down into the molten material below, and were cemented together in a matrix of fresh lava as a pseudo-breccia. In many cases the outlines of the fragments are extremely indistinct and the patches merge gradually into the surrounding rock; this points to a partial melting-down of the fragments, and to a greater or less absorption of them into the liquid magma; in the plastic state to which they were thus reduced they were dragged out into long wisps or streaks in the direction of flow. These features are well shown in the Carn Pica rocks [243], [280], and [240]. Such re-cemented breccias have been described by Harker in the Cross Fell inlier, and Brögger has ascribed a somewhat similar mode of origin to certain rocks in the Christiania district.

(*d*) Chemical Composition of the Volcanic Rocks.

The highly acid composition of the volcanic rocks in this area is apparent both in the field and under the microscope. But chemical analysis brings out several points of interest.[1] The dark bluish-grey rock [76] from Goodwick (described on p. 162), with a specific gravity of 2·60, has the following composition (A).

	A.	B.
SiO_2	68·01	72·06
Al_2O_3	17·48	14·87
Fe_2O_3	0·41	1·33
K_2O	7·08	5·90
Na_2O	5·77	4·11
MgO	0·46	1·26
CaO	trace	trace
H_2O	0·73	0·26
	99·94	99·79

Another felsite [203] from Carn Gelli (described on p. 163) has a higher percentage of silica. The specific gravity is 2·70. See analysis (B) above.

These two rocks have a remarkably high percentage of alumina, potash, and soda combined. In the first these three components make up 30·33 per cent. of the whole, and in the second 24·88 per cent. of the whole. Such a proportion militates against classing them with the rhyolites proper, and leads us to compare them with the quartz-keratophyres of the Continent. Keratophyres were first described by Gümbel in association with the Cambrian beds of the Fichtelgebirge,[2] and since then our knowledge of these rocks has been considerably increased by the researches of Lossen in the Harz.[3] The high percentage of alkalies in the keratophyres at once recalls the leucite- and nepheline-bearing rocks, but these minerals are nevertheless absent. There is considerable variability in the amount and relative proportions of the alkali-felspars, in the percentage of silica, and in the texture of the rocks. Thus some are compact and hornstone-like in appearance, and Rosenbusch states that those with a microfelsitic facies have as yet been scarcely noticed in Europe.[4] Howitt describes some of Palæozoic age in Gippsland,[5] associated with intrusive masses. Rosenbusch states that some of the Welsh rocks, which are usually termed quartz-felsites, would be more correctly named 'quartz-keratophyres'; and he instances the Llyn Padarn rocks and the nodular felsites of Conway Falls, Digoed, Cwmyglo, described by Bonney, Cole, and others. The potash-soda and soda-felsites of Co. Wicklow described

[1] The analyses have been made for me by Mr. F. E. Tadman, of Queens' College, Cambridge, in the University Chemical Laboratory.

[2] 'Die paläolithischen Eruptivgesteine des Fichtelgebirges,' Munich, 1874, p. 45.

[3] Zeitschr. Deutsch. geol. Gesellsch. vol. xxxiv. (1882) pp. 199, 455, and vol. xxxv. (1883) p. 215.

[4] 'Mikroskopische Physiographie,' 2nd ed. vol. i. (1885) p. 440.

[5] 'The Rocks of Noyang,' Trans. Roy. Soc. Victoria, vol. xx. (1883) p. 19.

by F. H. Hatch[1] show many points of resemblance with those from the Fishguard area, and the author suggests that the striated felspars may belong to Rosenbusch's anorthoclase series,[2] analogous to the soda-orthoclase or soda-microcline described by Förstner in the liparites of Pantelleria,[3] by Brögger in the augite-syenite of Southern Norway,[4] and by Miers and Fletcher from Kilimanjaro.[5]

The almost entire absence of lime in the Irish and Fishguard examples and of microperthite, which Lossen states is generally present, are important points of difference from the foreign keratophyres. The analyses of some of the British and foreign rocks are here given for comparison:—

	I.	II.	III.	IV.	V.	VI.
SiO_2	71·12	70·97	73·6	75·6	68·01	72·06
Al_2O_3	14·58	13·84	13·8	12·8	17·48	14·87
Fe_2O_3	1·69	3·21	0·5	...	0·41	1·33
MgO	0·15	0·20	0·7	0·4	0·46	1·26
CaO	1·50	1·26	0·6	0·1	trace	trace
Na_2O	3·26	6·27	3·2	3·0	5·77	4·11
K_2O	6·01	1·57	4·3	5·6	7·08	5·90
H_2O	0·95	0·74	...	...	0·73	0·26
TiO_2 (ZrO_2)	.....	0·25				
FeO	.....	0·78	2·4	1·9		
MnO	.....	0·12				
P_2O_5	.....	0·08				
CO_2	.....	0·79	Loss on ignition. 0·6	Loss on ignition. 0·5		
	99·26	100·08	99·7	99·9	99·94	99·79
Specific gravity...	.....	.....	2·658	2·626	2·60	2·70

I. Liparite from the Island of Ponza (Kalkowsky).
II. Quartz-keratophyre from the Harz (Jacobs).
III. Potash-soda felsite, Co. Wicklow (Hatch).
IV. Do. do. do.
V. Potash-soda felsite [76], Goodwick, Pembrokeshire (Tadman).
VI. Potash-soda felsite [203], Carn Gelli, near Goodwick (Tadman).

An analysis of the dark olive-green 're-cemented lava-flow' (mentioned on p. 176) gives the following result (C):—

	C.	D.
SiO_2	72·33	76·00
Al_2O_3	13·78	15·01
Fe_2O_3	4·02	0·34
K_2O	5·05	5·28
Na_2O	1·64	1·54
MgO	1·59	0·95
CaO	trace	trace
H_2O	1·34	0·74
	99·75	99·86
Specific gravity...	2·65	2·60

[1] Explan. Mem. Sheets 138, 139, App. F. p. 49, Geol. Surv. Ireland (1888); Geol. Mag. 1889, pp. 70, 288, 545; Brit. Assoc. Rep. (Newcastle, 1889) p. 568.
[2] 'Mikroskop. Physiogr.' 2nd ed. vol. i. (1885) p. 550.
[3] Zeitschr. f. Krystallogr. vol. viii. (1884) p. 125.
[4] 'Die silur. Etagen 2 & 3,' Christiania, 1882, p. 261.
[5] Mineral. Mag. vol. vii. 1887) p. 131.

But this rock [260] shows, under the microscope, other features which exactly correspond with those in a nodular rock from Pen y Chain, Pwllheli, associated with pyromerides.[1] In ordinary light under the microscope it shows a finely-granular, dark olive-green matrix, in which lie more or less circular areas marked out by fairly broad transparent lines, and divided up into circular or polygonal patches by similar lines; these patches are of the same granular character as the matrix; and each circular area curiously reminds one of a sporocarp containing spores, or of encysted gregarines. There are also visible clear vesicles having their centre filled with a clear greenish or violet-coloured substance, or with dirty-brown matter containing a few porphyritic felspars. With crossed nicols there are no outlines to the vesicles visible, but the greenish or violet centres are still plain. A few porphyritic felspars, twinned on the Carlsbad type and with rounded angles, occur in the matrix, which is for the most part cryptocrystalline, but here and there has become microcrystalline and minutely spherulitic. Irregular shreds and patches of a clear olive-green substance occur in it. There is a trace of phosphate of lime in this rock, suggesting the presence of a little apatite.

A mottled or 'blotchy' rock from Coch y Ceiliog was analysed, owing to the supposed occurrence of pinite in it. The rock is an altered coarse tuff, and the analysis (D) gives the above result.

The specific gravities of the lavas vary between 2·60 and 2·76, but most of them are about 2·63. The micropoikilitic varieties have a slightly higher (2·65) specific gravity, but no definite relation between the extent of the development of the micropoikilitic structure and the specific gravity is traceable, although this may be owing to the fact that the *same* lava-flow cannot be traced through the several stages, by reason of the impersistence and varying composition of each bed.

(*e*) The Intrusive Rocks.

(1) *Distribution and Structure.*

The general distribution of these rocks has already been briefly mentioned, and a few details may here be added.

The common correspondence of the strike of the intrusives with the strike of the bedded series suggests for the lenticular masses a laccolitic origin. But the great Strumble Head mass, reaching from the extreme west of that peninsula to Ciliau in the east, with the southern spur through Llanwnda, does not belong to this category.

The distribution of the intrusive masses is better seen by a glance at the map (Pl. V.) than by any description.

The joints that traverse these rocks are of several types. Commonly the joint-planes break up the mass into irregular blocks of

[1] Through the kindness of Miss C. A. Raisin I was enabled to examine a section of this rock.

all shapes and sizes, so that the weathered summits and slopes of the bare rocky prominences are covered with a confused assemblage of tumbled blocks. Such is the case at Llanwnda, and on the 'Carns' of the Llanllawer mountains.

Fine spheroidal jointing, such as has been described by Prof. Bonney in his important paper in 1876,[1] is well shown near Aber Clawdd Pridd, and less perfectly near Porth Lleuog and in the rotten decomposed rock on the western slopes of Fishguard Harbour.

Two excellent examples of columnar jointing have come under my notice; one occurs near the jetty on the east side of Fishguard Harbour, and the other on Pen Anglas. In the former case the hexagonal columns are fairly regular in shape, and nearly horizontal in position.

Brecciation in place, such as has been described in the Dimetian of St. David's by Prof. Hughes,[2] is exhibited in the diabase of the little harbour of Parc y Morfa, east of Castle Point.

(2) *The Crystalline Intrusive Rocks and their Mineralogical Composition.*

There is a considerable number of varieties of intrusive rocks in this area; basalts, dolerites, andesitic dolerites, with tachylytic and variolitic modifications, as well as diabases and gabbros, have been recognized. Most of the crystalline rocks are of a dark greenish colour, and fine in grain. Some are extremely coarse-grained, and the large augite- and felspar-crystals are very conspicuous, as in the Llanwnda gabbro. In some there are patches or veins—contemporaneous, segregatory, or subsequent—of a finer grain, as in the Y Garn diabase, near Pont Iago. Others are uniformly extremely fine-grained, and are black, heavy rocks, as, for example, a basalt near Penrhiw. Others are vesicular, as near Fishguard Harbour and on Carn Hendy. Others, again, look almost white from the abundance of the felspathic element, as in the case of some andesitic dolerites on Carn Ingle.

Others, owing to secondary processes, have become violet-grey, compact rocks of a tough siliceous character, with subconchoidal fracture and with spherical amygdules of quartz which have the appearance of white pebbles on weathered surfaces. Near Trwyn Llwyd, on Pen Caer, such rocks occur.

The principal primary mineral constituents of these rocks are felspar, pyroxene, and iron oxides; but the relative proportions of these are subject to great variation. Thus we get some rocks consisting mainly of felspar (trachytic differentiation), as in the case of those from Garn Fechan, Carn Ingle, and Rhos Hes Cwm, near Dinas. Others are composed almost entirely of large crystalline plates of augite (pyroxenitic differentiation), and of these we find an example in the Llanwnda gabbro. Others again contain iron oxides in great abundance, as in the basalt of Carn Hendy, in which

[1] Quart. Journ. Geol. Soc. vol. xxxii. (1876) p. 140. [2] Geol. Mag. 1883, p. 306.

grains and crystals of magnetite are so thickly crowded together as to render it almost opaque under the microscope; and in another rock, from an old quarry near Manorowen Mill, similar characters are found. These important differences in composition must be ascribed partly to a segregation or concentration of the constituents of these minerals in certain portions of the unconsolidated and uncrystallized magma, and partly to successive intrusions of varying composition. While it was yet fluid a kind of lateral secretion and interchange of material must have gone on, for there is no sign of movement subsequent to the formation of the crystals of the minerals except perhaps in the case of the magnetite.

The felspars belong for the most part to the oligoclase-andesine set. As a rule, the felspar-crystals are of one generation only, and present the usual lath-shaped forms in section; but two generations are observable in some cases [259], [43], [109], in which the earlier generation consists of large, well-formed twinned crystals, and the later of small, interlaced, lath-shaped crystals.

In many cases the latter contain granular cores or inclusions, especially when the rock belongs to the 'slaggy' type; and skeleton-crystals are very common in this type, together with feathery aggregates of felspathic fibres [101], [257], [227], [263], etc. (see also *infra*).

In the majority of cases the felspars have clearly preceded the other minerals (with the exception of the iron oxides) in crystallizing out from the original magma; and their outlines are moulded by the other constituents. In some cases the predominant mineral in the rock is felspar, as on Carn Ingle [304], [308], and [350].

The augite is usually of later date than the felspar, but sometimes belongs to nearly the same period of crystallization, as in the coarse-grained, gabbro-like rocks of Ciliau and Carn Gowel [3], [107], in which almost or partly idiomorphic crystals occur.[1] Good crystals also are found in a rock from Castle Point, Fishguard [62]. Large ophitic augites are seen in the Henner School mass, and also in dolerites from Fishguard Harbour [72], and elsewhere [108], [241]. A peculiarly minute ophitic structure is shown by the augite in a rock [267] from the neighbourhood of Drittwg, Strumble Head.

A rather exceptional type, in which the augite occurs in abundant, large, fresh, crystalline grains [310], but not ophitically, though it is rather later than the felspar, leads us on to the 'granulitic' type of Judd,[2] in which the augite is in a granular condition. This is largely represented in our area [252], [282], and [43].

A dark grey rock from the eastern side of Porth Sychan shows fairly well-formed crystals of augite, in addition to granules of this mineral. Perhaps the latter may be due to a shattering of some of the crystals by internal movements in the unconsolidated magma.

[1] See Harker, 'The Bala Volcanic Series of Caernarvonshire,' pp. 81, 82.
[2] Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 49.

Iron oxides occur both as magnetite and ilmenite. The latter is found in the coarse-grained rocks, and usually as skeleton-crystals with the characteristic decomposition-product leucoxene [107], [24], [60], and [82].

Magnetite is not generally abundant. When found it is in the form of minute rods, grains, and crystals [10]. But in some basalts, etc., it occurs in considerable quantity, as in the Carn Hendy rock [293], and others [326], [259], and [237].

Apatite is rare, but when found has the usual form of slender prisms [28]. Interstitial matter is present in the basaltic, tachylytic, and variolitic rocks; and almost invariably we find, as we should expect, that its presence in any abundance indicates the proximity of the margin of the intrusion [286], [273], and [275].

Variations in the texture of the rock may be observed even in the same slide [288], and probably point to the later injection of matter of a slightly different composition into the unsolidified mass, or to the inclusion of earlier consolidated portions, or to the differentiation *in situ* of the molten magma. Flow-structure is even indicated in some cases by the parallelism of the felspar-crystals [339].

The secondary minerals call for some special notice. The usual products of the decomposition of the original minerals are present in most of the rocks, and of these secondary minerals chlorite is the commonest: it may occur either as structureless pale green patches, or as groups of radiating fibres lining cavities or filling up the interstices between the other minerals. In a few cases the pale structureless patches contain circular clear spots, the origin of which is doubtful. With crossed nicols the chlorite is almost isotropic, but these spots are seen to consist of quartz or chalcedony, [19] and [106]: sometimes the spots have a dark semi-opaque centre, but only in one instance [247] is each spot a spherulite giving a perfect black cross with crossed nicols.[1]

Some of the greenish decomposition-minerals appear to be of a serpentinous nature, but olivine has not been detected in any of the rocks.

Epidote is common as a secondary product, and is found as small grains or crystals. Calcite, in large crystalline plates with well-marked cleavage, is especially abundant in the sills on the western side of Fishguard Harbour; and dolomite also occurs here. The sills at this locality have suffered not only much chemical alteration, but also considerable mechanical movement and crushing. The planes of the cleavage thus set up are marked by shining black flakes of a chloritoid mineral, [59] and [30]. Calcite occupies large patches of the rock and forms irregular pseudamygdules, so that when it has subsequently been removed by solution these weathered-out cavities give to the rock a pseudo-scoriaceous appearance.

The associated cleaved tuffs of vesicular lavas, lapilli, etc., of

[1] Mr. S. H. Reynolds, M.A., has recently pointed out to me similar structures in some Kildare basalts; and I have met with them also in dolerites from Co. Waterford.

which the cavities also have been infilled with carbonate of lime, near Fishguard Harbour, greatly resemble at first sight these rocks in the field. The intrusive rocks are, however, readily recognized under the microscope [78], [49], [65], [15], and [88].

Secondary quartz is found in several localities in considerable abundance in the intrusive rocks. It occurs as irregular grains or patches, replacing either portions of the groundmass or the original crystalline constituents [71], [60], and [350]. On the northern coast of Strumble Head at Aber Morgan, the diabase is of light-grey colour and has a subconchoidal fracture mainly due to this infiltration of quartz [275]; and in a tough, violet-grey, fine-grained rock from the cliffs near Globo Fawr [251] the silica not only replaces much of the groundmass and some of the felspar-crystals, but forms spherulites and fills cracks and vesicles to such an extent as to render the rock totally unrecognizable in the field as a diabase. The quartz-filled vesicles weather out on the surface like white pebbles.

Leucoxene is a common alteration-product of the ilmenite, and pyrites is to be seen in greater or less quantity in nearly every specimen of diabase.

(3) *The Variolitic and other Varieties of the Intrusive Rocks.*

There are several exposures of two closely-allied types of intrusive rock which have many points of resemblance with tachylytes and variolites, and merit careful description.

The glassy or tachylytic variety possesses a peculiar 'slaggy' appearance under the microscope. Some of the best examples come from Garn Fawr near Pwll Deri. In the field and to the unaided eye the rock merely resembles a very fine-grained compact 'greenstone'; but under the microscope we see, in slides [53] and [101], pale green granules arranged in lines in single or multiple series, and more or less fused with each other into rod-like structures; these rods lie in groups parallel one to the other. The relation of the length of an individual rod to its breadth is on an average about 30 : 1, while the separate rods frequently show curvature, and are furnished with short parallel branches which arise at an acute or right angle to the main stem. The groups of parallel rods lie at all angles to each other, and each group consists of two to eight rods. Detached granules with or without a linear arrangement represent the rods in other parts of the groundmass; and all stages of the fusion of these separate granules—'globulites'—into one of the rods or branches may be seen. Some of the parallel rods thus composed are stumpy, and the proportion of the length to the breadth may be as low as 3 : 1. Minute pale green granules of the same nature are scattered profusely throughout the groundmass. These 'globulites' and the long rod-like 'crystallites' which they build up remind one of the augite-skeletons in the Arran pitchstone,[1] of the rod-like structures of little grains, etc., of augite in the

[1] Allport, Geol. Mag. 1872, p. 536; Rosenbusch, 'Mikroskop. Physiogr.' 2nd ed. vol. i. (1885) pl. iii. fig. 3.

Weiselberg pitchstone,[1] and of the crystallites in common window-glass figured by Vogelsang.[2] Liebe has described parallel systems of iron-ore crystallites in an East Thuringian variolite.[3] With crossed nicols felspar-fibres in parallel systems, in the shape of definite crystals and showing twinning, or interlaced and crossing in all directions, become visible; and a few skeleton-crystals of felspar may also be detected. Rosenbusch figures very similar feathery aggregates and bundles of felspar-crystals in a Caucasian trachyte[4]; and the skeleton-crystals remind one of those figured by the same author in pl. iii. of his 'Rock-forming Minerals' (Iddings's translation), and described as occurring in the Weiselberg pitchstone in the semi-vitreous groundmass.[5] In another slide [101] (Pl. VI. fig. 7) the above-described structures are all present, but a further stage in the fusion of the felspathic fibres into definite crystalline individuals is shown; and, in addition to long felspathic fibres and numerous skeleton-crystals of felspar, definite porphyritic felspar-crystals with a central semi-opaque axis occur, similar to those described by Cole and Gregory in the variolite of Mont Genèvre.[6]

In another rock-specimen, also from Garn Fawr, we see in the section [90] under the microscope that the pale green augite-crystallites lie in places without any order, and are more numerous, more interlaced, more slender, and more 'pinnate' with side branches. In this section also there are many short, well-formed lath-shaped felspars, with visible twinning and an extinction-angle of about 8°, while skeleton-felspars are very scarce (Pl. VI. fig. 6).

Another section from a specimen chipped off the northern craggy spur of Garn Fawr [287] is distinguished by the presence of some large porphyritic lath-shaped felspars occurring in groups and containing inclusions of the groundmass, etc. In all these examples from Garn Fawr the groundmass gives an indefinite reaction with crossed nicols, and appears to have been originally of a glassy nature.

This tachylytic[7] variety is not confined to Garn Fawr, but occurs near St. Degan's Church, on the northern coast of Strumble Head [272]. In this it is worthy of remark that the augite-crystallites and granules are most thickly grouped around the felspar-crystals to which they form a dark border, and in places a local bleaching of the groundmass has taken place by reason of this local aggregation—as in the case of the Eskdale dyke. Near Globo Fawr, Bigney, and Caerlem the tachylytic type is also found [268].

In many important features these rocks correspond with the

[1] Rosenbusch, *op. cit.* 2nd ed. vol. ii. (1887) p. 501.

[2] Vogelsang, 'Die Krystalliten,' Bonn, 1874, pl. viii.

[3] Liebe, 'Schichtenaufbau Ostthüringens,' Abh. z. geol. Specialk. v. Preussen, vol. v. Heft 4 (1884) p. 110.

[4] 'Mikroskop. Physiogr.' 2nd ed. vol. i. (1885) pl. iii. fig. 4.

[5] In a Pantellerian tachylyte Förstner has described similar branching fern- and feather-like felspar-microlites, Min. u. petr. Mitth. vol. xii. (1891) p. 510.

[6] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 313.

[7] The term 'tachylyte' is used here in a broad sense, and corresponds to Zirkel's 'basaltic obsidian,' 'Lehrb. d. Petrogr.' vol. iii. p. 91 (ed. 1894).

basalt-glasses, variolites, and marginal modifications of diabase described by Cole and Gregory,[1] Judd,[2] Groom,[3] and others; and we shall see immediately how closely linked they are with certain others which bear a strong resemblance to the variolitic rocks of the Lleyn peninsula in North Wales described by Miss Raisin.

The second variety of this group of rocks, while possessing the general appearance and constituents of the tachylytic variety, is as a rule destitute of the groups of parallel augite-crystallites. But no hard-and-fast line can be drawn between the two varieties, as many intermediate forms occur. The characteristic feature, however, of this second variety is the tendency of the felspathic fibres and crystallites to group themselves into spherulitic aggregates (Pl. VI. fig. 2). These aggregates appear as semi-opaque greyish spots of small size, under the microscope, and are roughly spherical in shape. They consist of minute radiating felspathic fibres, with a ring of granules and dusty material round the whole spherule. Most of them have indefinite boundaries; some are axiolitic and have formed around felspar-crystals. With crossed nicols an indistinct black cross is visible in some of the spherulitic growths. Various stages in the development of these radial groups are to be found in a series of slides which I have had prepared. The most perfect examples are from Garn Fechan, adjoining Garn Fawr, where the tachylytic variety just described is found. The radial groups are best shown in [257], [226], [283], where most of the spots have definite boundaries of augite-granules and dusty material. In other slides—[263], [227], [303]—the spots are more irregular and less clearly marked out, while the felspar-crystals in the rock are fringed with divergent felspathic fibres.

Through the kindness of Miss Catherine Raisin I have been able to examine her slides of variolitic rocks from the Lleyn; and I readily identified the radial structures in my Pembrokeshire rocks with the 'incipient varioles' mentioned by her. The structures are undoubtedly identical, and the spheroidal diabase of Porth-din-Lleyn, in which these incipient varioles are well shown, has features exactly similar to those in the spheroidal diabase [283] of Porth Lleuog, Strumble Head. The Porth-din-Lleyn rock has been described by Miss Raisin,[4] and I have had the privilege of seeing the actual slides and of thus comparing the structures side by side. Hence we may chronicle the discovery of another British locality for variolitic rocks in addition to those already known in Anglesey, Co. Wicklow, Co. Down, the Lleyn peninsula, and Carrock Fell. However, the variolitic structures seem to be merely incipient and rudimentary in all the Strumble Head examples, and they are rarely visible macroscopically. The varioles, also, in the latter rocks have not been found as pea-like bodies on weathered surfaces, as is the case in the Lleyn examples; and ferruginous varioles of

[1] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 295. [2] *Ibid.* vol. xxxix. (1883) p. 444.
[3] *Ibid.* vol. xlv. (1889) p. 298. [4] *Ibid.* vol. xlix. (1893) p. 155.

Miss Raisin's second type (*op. cit.* p. 152) are not present in any instance.

I am quite in accord with Miss Raisin's view that the variolitic structure is not necessarily developed at the exterior of the intrusive mass, and is not always connected with the exterior of spheroids. In the case of Garn Fechan, for instance, the whole 'Garn' from its northern to its southern borders has the incipient varioles more or less developed, without reference to the propinquity of the margins.

Variolite was defined by Cole and Gregory as a 'devitrified spherulitic tachylyte, typically coarse in structure.'[1] The association of the devitrified tachylytic rock of Garn Fawr, which forms in itself a huge mass, and is the western termination of the intrusive belt that stretches from Pwll Deri to Pont Iago, with the adjoining smaller variolitic mass of Garn Fechan, which merges insensibly into the Garn Fawr mass and certainly constitutes part of the same intrusion, suggests strange conditions of cooling and crystallization. We must get rid of the impression produced by the present configuration of the locality in order to form an accurate idea of the actual circumstances at the time of the intrusion. A probable explanation seems to me that the molten material was forced between highly tilted strata in such a way that merely one end of the laccolite approached the surface while the rest of it was deeply buried beneath the superincumbent strata, and that owing to its nearness to the surface of the ground, or to the composition or structure of the beds surrounding this end, or to all combined, this portion of the laccolite cooled with considerable rapidity. It has been pointed out by Miss Raisin that spherulitic structures tend to form in parts where the cooling is not rapid enough to give rise to a homogeneous glass, nor slow enough to produce well-formed crystals.[2] It is just in this intermediate but indefinitely-bounded zone that we find the varioles occurring at Garn Fechan.

In all these variolitic and tachylytic rocks the forms of the felspars are of special interest. Perfect crystals are rare, and occur porphyritically. Skeleton-felspars are exceedingly common, and fork-shaped terminations are often seen. The bent and wavy felspar-microlites have generally a dark granular core, which represents an included portion of the undifferentiated magma and is not due to secondary alteration. The fine fibre-like microlites are often of considerable length. The shorter microlites are grouped in tufts round the ends of the porphyritic felspar-crystals, or form a fringe round them. Between this condition and that of independent axiolitic or spherulitic groups there is every gradation to be found. One may therefore infer that the 'incipient varioles' are here intimately connected with the second growth of felspar-crystals. And that they were formed comparatively early in the consolidation of the rock appears indicated by the fact that the fibrous fringe

[1] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 330.
[2] *Ibid.* vol. xlix. (1893) p. 156.

round the felspar-crystals sometimes maintains not only the crystalline form and faces of the crystal which it edges or terminates, but even the twinning, and that many of the independent groups of fibres merely differ from the 'incipient varioles' by possessing the crystallographic outlines of a felspar-crystal instead of a spherical shape and radial structure. We can in fact see felspar-crystals in the process of being built up of fibrous microlites; and I would ascribe their period of formation, together with that of the 'incipient varioles,' to the general consolidation-period of the rock. It is difficult, if not impossible, to suppose that they were formed by a process of secondary devitrification posterior to the solidification of the rock.

There is a local variety of the Garn Fechan rock of considerable interest. In it we find the sole instance of micropegmatite. The groundmass in this rock [230] is composed of a granophyric intergrowth of quartz and felspar, as in an ordinary acid granophyre. The micropegmatite fills up the interstices between the lath-shaped twinned felspar-crystals and the rhombic pyroxenes, and seems to have been left as a sort of mother-liquor after these minerals had crystallized out of the original magma. It reminds us of some of the Carrock Fell rocks. The rhombic pyroxene (a kind of bastite) is pleochroic, and fibrous in appearance; and there is a large amount of greenish serpentinous material present, as a decomposition-product. Original clear quartz-grains are abundant. The specific gravity of this rock is 2·67.

The greater acidity of all these associated rocks which their mineralogical composition indicates, may be due to the fusion and incorporation of some of the acid lavas which they traverse. None of these Fishguard variolitic rocks have the 'pseudocrystallites' of the Continental examples.

There is a rock of great interest occurring in a field near Caerlem Farm, on the north side of Garn Fawr, showing many features in common with these Garn Fawr and Garn Fechan rocks. The specimen from which the slide [262] was prepared forms a narrow selvage to the boss of rock whence a previously-mentioned variolitic rock [263] was obtained. Its high specific gravity at once arrests attention, being 3·05, while that of the adjacent rock [263] is only 2·93 and those of the tachylytic varieties [101] and [287] are only 2·68 and 2·70 respectively

The microscopic examination reveals other peculiarities, in the presence of numerous spherical or elliptical amygdaloids and of perlitic cracks. Some of these amygdaloids are lined with clear quartz-grains, forming a zone of nearly constant breadth (that is, about $\frac{1}{8}$ diam. of amygdaloid): the centre of these is filled with fibrous radiating groups of chlorite; others are entirely occupied by quartz; others again have a hollow centre. Epidote in irregular patches or crystals is seen in the central or outer quartz-zone of some. Others have an outer continuous zone, or a central kernel, of a dichroic mineral with a high index of refraction; this mineral

also occurs in minute prisms or detached patches in the outer quartz-zone of some of the amygdaloids. It gives a sea-green colour parallel to the length of the crystal and to the shorter diameter of the nicol, and is colourless in a position at right angles to this. The extinction is straight. From these characters I believe it is one of the epidotes.

The amygdaloids represent original vesicles. After the absorption, condensation, or escape of the gas the cavities thus formed became more or less infilled with mineral matter. The dark line which surrounds most of these amygdaloids seems due to some corrosive action of the gas on the groundmass. The perlitic cracks in this rock point to its original glassy condition; some of them have been enlarged and filled in with quartz or epidote, and magnetite in granules has collected along them.

This slide [262] also shows two corroded felspar-crystals with crowds of dark brownish microlites diverging from their borders, while the surrounding groundmass is devoid of such structures. There are also a few spongy-looking 'clots' of crystallites and granules which represent feebly the well-developed 'nodules' of a rock from Penrhiw Farm, near Goodwick, which will now be described.

This Penrhiw rock is another variety of the glassy intrusives, and it may be appropriately called the 'nodular' variety. In the hand-specimen this rock has not the least appearance of an intrusive mass, but rather that of a nodular rhyolite; it is of a glaucous-green colour, with circular white spots, each of which has a violet centre; these are not, however, the 'nodules,' but only amygdaloids of quartz, etc.; the 'nodules' themselves are irregularly oval patches, $\frac{1}{4}$ inch or so in length, and of an opaque whitish appearance. The fracture of this rock is subconchoidal, and resembles that of a fine-grained felsite.

Under the microscope we notice many points of resemblance to the tachylytic variety: for instance, the parallel augite-crystallites, and the linear rows of granules; but there are also larger spherical grains of a semi-opaque greenish-brown mineral, and groups of crowded parallel minute crystallites. Variations occur in the relative abundance of the different elements. The 'nodules' are rather irregular ovals, measuring $\frac{1}{4}$ inch or less in length, and have a darkish, almost opaque, spongy-looking outer portion, the pores and interstices of which are filled with secondary quartz; the central part is of a pale brownish-yellow colour, with fine dark rods and fibres (crystallites), similar to those in the groundmass, either radiating towards the centre or in feathery groups. A skeleton felspar-crystal is seen in the centre of one 'nodule,' but as a rule no definite felspathic elements are recognizable. The 'nodules' are frequently marked off plainly from the groundmass by concentric cracks or a dark granular thin coat, and are more or less irregular in shape. The dark granular outer coat or border is particularly well-marked around the nodules in one slide [40].

The 'pale green oval spherulites, about $\frac{1}{4}$ inch in length,' described by Miss Raisin as occurring in the Deunant and Aberdaron variolites,[1] bear a very close resemblance to these nodules, and indeed show no important points of difference; but I can see no reason why the structures in question should be considered spherulitic, as they show little or no radial arrangement.

I have had the advantage, through Miss Raisin's courtesy, of examining her slides of these rocks; and it appears to me that we have to deal with structures similar to some described by her in the nodular felstones of the Lleyn. The cracks which mark off the 'nodules' from the groundmass gain therefore, in my opinion, considerable importance in the Penrhiw rock, since they indicate the mode of origin of the nodules, namely, by contraction. Prof. Bonney, who has seen my slides, makes the additional suggestive remark that the groundmass may have shown an original 'lumpiness' or 'clotted' character, indicating local differences of composition and leading to the formation of the nodules.

In two cases, [31] and [40], portions of the groundmass, which in ordinary light are seen to be free from the greenish rod-like structures, but crowded with minute spherical granules, show with crossed nicols numbers of secondary spherulites which give a black cross. In some cases they appear to have been formed around small, circular, granular brown spots, but in others these spots occur promiscuously in them. The fine crystallites, etc., traverse the spherulites indifferently and without deflection or alteration of any kind, thus bearing testimony to the secondary origin of the spherulites. In one slide [31] undoubtedly secondary spherulites occur in a vesicle.

The true amygdaloids of spherical shape, which may be compared with those in the previously-described Caerlem rock [262], are mostly composed of microcrystalline quartz, but some are of clear crystalline quartz-grains. The groundmass, where not spherulitic, has an almost isotropic or a blurred appearance with crossed nicols, [224], [31], and [40].

A rock in close association with these 'nodular' varieties shows perlitic cracks with great distinctness [77]. None of the rod-like crystallites and very few of the granules are present in this rock. But the groundmass looks as if it were composed of dense multitudes of overlapping, minute, brownish-yellow prisms with a high index of refraction. Each portion of the groundmass enclosed by a perlitic crack has this appearance in the central portion, but it is surrounded by an outer zone of a pale brownish-yellow, homogeneous substance. Prof. Bonney has called my attention to certain points in the character of the perlitic cracks which are of especial interest. Each crack is indicated now by a dark, thread-like line, on each side of which lies a clear transparent broad line, and outside of this lies the brownish-yellow homogeneous zone which has been mentioned as surrounding the separate patches of the groundmass. Occasionally

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 154.

two dark, thread-like perlitic cracks run close to each other in a parallel or sinuous manner, and have only a clear, transparent, broad line or narrow zone between them. In some cases the walls of the crack have gaped apart more widely, so that the dark line is thick and granular, representing the infilled crack. The perlitic cracks have in fact acted as channels, along the sides of which alteration of the surrounding rock has taken place.

There is another rock from Penrhiw which completes the strange trio from this spot. It occurs as part of the same mass as the 'nodular' and perlitic varieties, and is the most distant of the three from the outer margin of the intrusive mass. In the field it is a pale greenish-grey rock, with minute black specks scattered through it. Under the microscope in ordinary light it shows [73] a clear, transparent groundmass, with feathery groups of felspar-fibres, parallel groups of clear spindle-shaped crystallites, flecks, grains, irregular little rods and threads of a semi-opaque, dark brownish substance, small circular patches of quartz, chlorite, etc., and long prismatic crystals with a high index of refraction and ragged ends which seem to tail out into spindle-shaped crystallites. These crystals with crossed nicols give bright polarization-colours, and extinguish at 40° to their length. They appear to belong to some pyroxene. Lines of flow are very apparent in this rock.

A basalt, with peculiar characters not found in any other in the district, occurs at Carn Hendy, near Ciliau. The groundmass [293] is composed of fine feathery bunches and radial tufts of felspathic crystallites, with an immense quantity of interstitial magnetite in grains and dust, which gives the rock a very dark colour and high specific gravity. It is also remarkable for the number of vesicles of all sizes and shapes, which are filled with serpentinous minerals, chlorite, and some epidote. Skeleton felspar-crystals and elongated slender felspars with an axial core of inclusions are also scattered throughout the groundmass. The rock somewhat resembles a vesicular ferruginous basalt north of Porth Oer, Lleyn peninsula, described and figured by Miss Raisin.[1] It belongs to the great northern intrusive mass of Strumble Head, but is a very distinct local variety, and is another indication of the composite nature of this huge intrusion.

Vesicles.—Nearly all the igneous intrusions are more or less vesicular in parts. But the vesicles have not all the same origin; for there are, firstly, the amygdaloids which fill up the cavities previously occupied by gas-bubbles, and these have usually a spherical shape. Secondly, there are the amygdaloids which occupy spaces that have been formed through the removal by solution of portions of the groundmass or of crystals of felspar, etc. These might be called 'pseudomorphic amygdaloids.' They are present in many of the rocks [282], [109], [78], and [10], and are usually distinguishable from the amygdaloids after gas-bubbles by their irregular shape.

Certain dark patches of interstitial matter, which in some cases

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 164 & pl. i. fig. 2.

are sharply marked off from the surrounding matrix and have the lath-shaped felspar-crystals of the groundmass arranged tangentially round them, occur in a diabase from Cwm Felin, north of Llanwnda, [271]. These patches are in fact nodular structures. They seem to be segregatory patches of the interstitial matter, and are generally completely free from any of the crystalline elements of the groundmass, but the lath-shaped felspars project into the outer portion of the patches when they are not sharply marked off. When the whole of a spherical or oval nodule has been removed by solution, and the cavity thus arising is filled up with cryptocrystalline silica, calcite, dolomite, etc., they have exactly the appearance of infilled gas-vesicles. But the co-existence in the same slide [271] of these amygdaloids in all stages of formation and of nodules partially removed and replaced at once shows that they cannot be pseudomorphs after gas-bubbles, such as have been described by Teall [1] in the case of the Tynemouth dyke.

The spherical amygdules in the outer coats of the spheroids of the diabase near Aber Clawdd Pridd seem, however, to be infilled vesicles, once occupied by gas. Miss Raisin, in her previously quoted paper on the Lleyn variolites, mentions vesicles occurring under similar conditions.

(4) *Specific Gravity of the Intrusive Rocks.*

There are some interesting points connected with the specific gravity of these rocks. The most crystalline members have, as we should expect, a higher specific gravity than the tachylytic and variolitic varieties. Thus the holocrystalline rock [108] of Henner School has a specific gravity of 3·00; it is practically a gabbro. Other rocks not quite so coarsely crystalline, [28], [107], and [15], vary in specific gravity between 2·93 and 2·94; while in the variolitic and tachylytic varieties [257], [226], [53], and [101] the specific gravity ranges between 2·67 and 2·68. But in each case, when porphyritic felspars are abundant, the specific gravity rises, as for instance in the Garn Fawr rock [287], where it is 2·70. The extraordinarily high specific gravity (2·93) of the tachylytic rock [263] from Caerlem and the still higher specific gravity (3·04) of the perlitic tachylyte [262] from the same place do not seem due to the secondary addition of iron pyrites, but to some process of segregation of the heavier more basic magma to the margin of the intrusive mass.[2] Rocks which consist almost wholly of felspar, such as [350], and might be classed with Gümbel's leucophyres, have naturally a lower specific gravity, as for instance (2·66) in the rock from Rhos Hes Cwm [350]. The Penrhiw nodular and vesicular rocks [40], [31], and [224] have a specific gravity of 2·70. The perlitic marginal modification [77] of these has a specific gravity of 2·92—another instance of the diffusion to the margin of the more basic part of the magma.

[1] Geol. Mag. 1889, p. 481 & pl. xiv.

[2] The recent paper by Mr. Harker on the Carrock Fell gabbro bears out this suggestion (Quart. Journ. Geol. Soc. vol. l. 1894, p. 311).

Where magnetite is very abundant the specific gravity naturally rises; thus in a rock from the neighbourhood of Manorowen [326] it is 2·90.

(5) *Chemical Composition and Age.*

One of the tachylytic rocks [101] from Garn Fawr has been analysed with somewhat astonishing results (Analysis E below). The microscopic characters of this rock have been described on p. 183.

	E.	F.
SiO_2	59·15	60·60
Al_2O_3	14·54	17·99
Fe_2O_3	12·31	7·31
K_2O	6·56	3·80
Na_2O	4·01	2·38
MgO	1·97	1·37
CaO	trace	2·41
H_2O	1·51	3·20
	100·05	99·06
Specific gravity	2·68	

There is evidence of phosphate of lime in (E).

The analysis (E) has so abnormal an appearance that Mr. Tadman took especial care with it and re-determined the silica, alumina, and iron sesquioxide, but with the same results as before. The presence of so much potash and soda in an intrusive rock with 59 per cent. of silica suggests the lamprophyres, but the high percentage of iron and the practical absence of lime make it impossible to regard this as a special mode of consolidation of a lamprophyric magma. An analysis by Mr. Collins of a minette from Nare Point, near Porthalla, is here quoted for comparison (F).[1]

The differentiation of an igneous magma, owing to the researches of Vogt, Wadsworth, Brögger, Teall, Harker, and others, is now established, and it allows of so great a latitude of interpretation that it is probably applicable to this case.

In a rock previously mentioned [230] from Garn Fechan, adjoining Garn Fawr, a micropegmatitic groundmass has been described. It seems probable, however, that it is of the nature of 'soda-microcline' as described in the rhomben-porphyry of Norway. The fact that the Garn Fechan rock occurs close to the Garn Fawr rock, of which the analysis has been given, has the same specific gravity and many of the same microscopic characters, while it forms part of the same intrusive mass, suggests a comparison with the analysis

[1] Some of the Carrock Fell variolites described by Harker (Geol. Mag. 1894, p. 551) have a closely similar percentage of silica. For example, the Scurth variolite, with 59·8 % together with almost identical microscopical characters. But Rosenbusch's 'weiselbergite' type of augite-porphyrite ('Mikroskop. Physiogr. d. Mass. Gest.,' 2nd ed. 1887, p. 501) bears a close resemblance in chemical composition, though with some important points of difference. An analysis of this augite-porphyrite by Hetzer gives: SiO_2 58·97, Al_2O_3 15·73 FeO 11·73, CaO 3·20, MgO 0·84, K_2O 0·65, Na_2O 5·43, and H_2O 3·25.

of this Norwegian rock. It will be seen that they closely agree, except in the percentage of lime. Some of Lossen's Harz keratophyres approach it in composition, but are deficient in iron oxides.

	G.	H.
SiO_2	54·89	59·15
Al_2O_3	16·48	14·54
Fe_2O_3 / FeO	10·05	12·31
K_2O	6·30	6·56
Na_2O	7·04	4·01
MgO	0·74	1·97
CaO	4·01	trace
H_2O	0·60	1·51
	100·11	100·05

G. Rhombenporphyr, Riis (Brögger).
H. Garn Fawr, Strumble Head (Tadman).

Age.—The age of the intrusive masses is not easy to decide. Some were injected prior to the tilting, cleavage, and faulting of the strata, and the fact that intrusive sheets are absent from the Silurian area to the north-east, according to the Geological Survey map, suggests that they are also pre-Silurian. But I am inclined to hold that the large Strumble Head masses were intruded subsequent to the tilting and folding of the beds, and the injection of the great northern mass, which apparently is composed of several distinct intrusions, may have been spread over a considerable period.

VI. Correlation with other Areas.

The adjoining St. David's area practically forms part of the same province, and frequent comparative allusions have been made to it in the course of this paper, so that it is unnecessary to repeat the points of agreement or difference. Until further fossil zones are discovered it would be injudicious to institute a close comparison with more distant regions.

A table of the succession of the beds (in descending order) in the Fishguard–Newport area is given for the convenience of the reader.

Llandovery (?).	Dinas Head Beds.	
Bala.	Black shales and slates of Porth Melyn and Pwll Deri, with the thin volcanic beds of Porth Sychan and Porth Melyn. Lower black shales, slates, and flaggy beds of Pwll Deri; and the central volcanic series of Strumble Head.	= Slates between the Upper Llandeilo Series and the coast from Coch y Ceiliog to Newport.
Upper Llandeilo.	Graptolitic shales (*Diplograptus euglyphus*, *D. foliaceus*, etc.) of Newport, and Pont Iago, Strumble Head: 150 feet. Tough calcareous beds with *Siphonotreta micula*: 10–20 feet (only near Newport). Grey tuff-beds near Newport: 50 feet. Felsites, breccias, and tuffs of Coch y Ceiliog to the River Clydach, and of the eastern side of Strumble Head (Goodwick, etc.).	
Middle Llandeilo (?)	Slates and flags of Goodwick Bay, and of Clydach Valley, etc.	

Lower Llandeilo.	*Didymograptus Murchisoni*-zone.	*a.* Black shaly beds with *D. Murchisoni*. *b.* Fossiliferous ashes of Saddle Point, etc. *c.* Felsites, tuffs, etc. of Castle Point, Bigney, etc. *d.* Black slates of Tower Hill with *D. Murchisoni*, etc.
Llanvirn.	Black slates of Blaen y Delyn with *Placoparia*, etc.	
Arenig.	Slates of the district south of Fishguard.	

In conclusion I take this opportunity of expressing my thanks to Mr. J. E. Marr, F.R.S., for valuable hints; to Mr. Alfred Harker, F.G.S., for some suggestions about the rocks; to Mr. H. Keeping for help in collecting; and especially to Miss Raisin and Prof. Lapworth, F.R.S., for the loan of slides and naming of graptolites, and to Dr. H. Hicks, F.R.S., for kind advice and encouragement.

EXPLANATION OF PLATES.

Plate V.

Geological Sketch-map of the Fishguard–Newport district. Scale: 1 inch = 1 mile.

Plate VI.

Fig. 1. Perlitic felsite, showing 'crackled china' structure and perlitic cracks. The lighter portions of the slide consist of pure secondary quartz; the darker portions are cryptocrystalline. From Bwlch Mawr, Dinas. (Slide 316.) ×68. See p. 172.

2. Variolite with incipient varioles, skeleton felspar-crystals, etc. in devitrified groundmass. From Garn Fechan, Strumble Head. (Slide 257.) ×68. See p. 185.

3. Porphyritic micropegmatitic groups in cryptocrystalline felsite. From Goodwick. (Slide 1.) ×68. See p. 162.

4. Ditto. The upper portion of this figure shows a rounded quartz-grain, surrounded by a later growth of micropegmatite. The lower portions show well the branching radiating processes and the composite nature of the groups. From Goodwick. (Slide 7.) ×68. See p. 162.

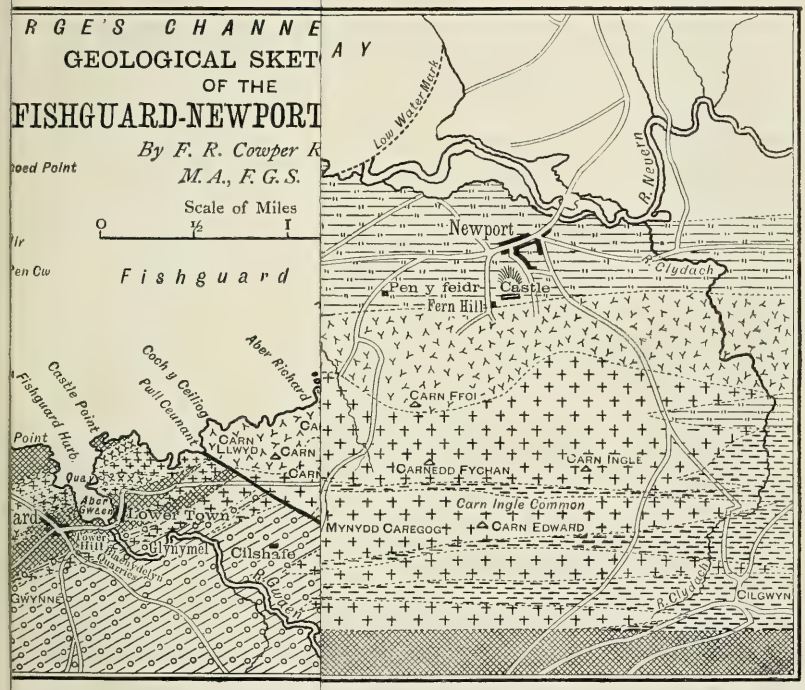
5. Ditto. From Goodwick. (Slide 21.) ×68. See p. 162.

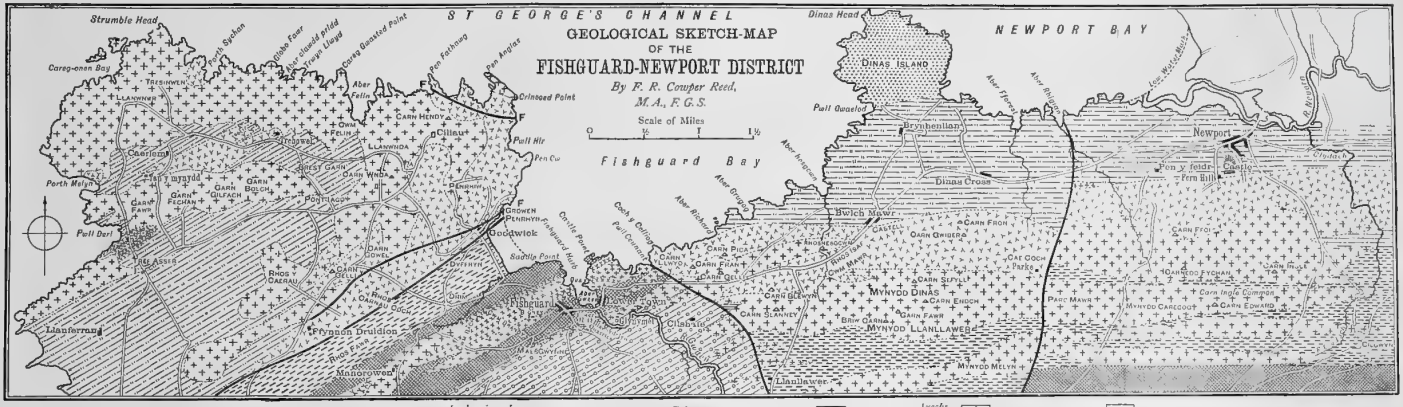
6. Glassy ('tachylytic') variety of andesitic dolerite, showing groups of parallel crystallites of augite, globulites, felspar-crystals, etc. in the devitrified groundmass. From Garn Fawr, Strumble Head. (Slide 90.) ×68. See p. 184.

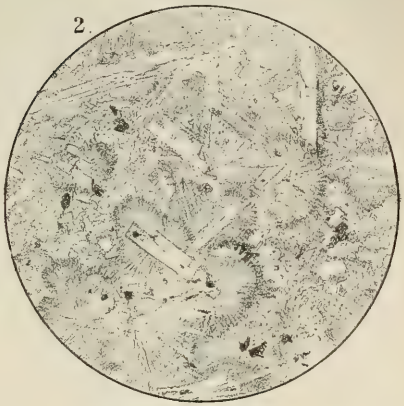
7. Ditto, showing skeleton felspar-crystals, and others with a granular core; also feathery aggregates of felspathic fibres, groups of parallel crystallites of augite, crystallites of magnetite, etc. in the devitrified groundmass. From Garn Fawr, Strumble Head. (Slide 101.) ×68. See p. 184 and Analysis E.

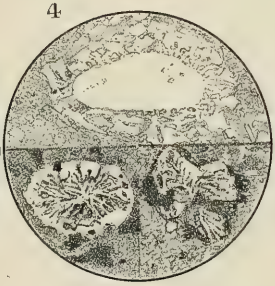
Discussion.

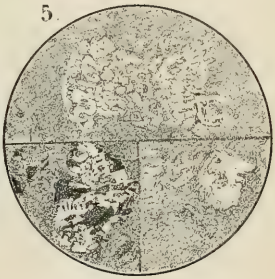
Dr. Hicks congratulated the Author on having worked out with such success the geology of a very difficult tract of country. He was particularly pleased to hear that the Llanvirn fauna had been discovered at Fishguard, as it marked a very definite horizon, and


R G E ' S C H A N N E
GEOLOGICAL SKET
OF THE
FISHGUARD-NEWPORT
By F. R. Cowper R
M.A., F.G.S.
Scale of Miles
0 ½ 1
Fishguard
Newport
Pen y feidr
Castle
Fern Hills
Low Water Mark
R. Nevern
R. Clydach
Cwm Clydach
Aber Richard
Cooh y Ceiliog
Pwll Caumont
Castle Point
Fishguard Harb
Point
CARN LLWYD
CARN FFOI
CARNEDD FYCHAN
CARN INGLE
Carn Ingle Common
MYNYDD CAREGOG
CARN EDWARD
Lower Town
Cilrhedyn
Cilshafe
Cilgwyn
Mid. Llandeilo.
Intrusive diabase, etc.
Faults.


GEOLOGICAL SKETCH-MAP
OF THE
FISHGUARD-NEWPORT DISTRICT
By F. R. Cowper Reed,
M.A., F.G.S.
Scale of Miles
ST GEORGE'S CHANNEL
NEWPORT BAY
Fishguard Bay
Strumble Head
Carreg-onen Bay
Trehowel
Llanwnda
Carnfawr
Garn Fechan
Garn Gilfach
Garn Bolch
Porthgain
Penberry
Pwllderi
Llanferran
Pen Anglas
Pen Fathaug
Aber Felin
Carn Henoy
Cilau
Pwll Hir
Pen Cw
Crinoaad Point
Goodwick
Crown Penrhyn
Fishguard
Fishguard Fort
Castle Point
Cadi y Cefnfaen
Pwll Cwmmaen
Carn Llwyd
Carn Pica
Carn Fran
Carn Gelli
Carn Sian
Carn Slanney
Carn Ffynnon
Carn Ffoi
Carn Fron
Carn Gwigera
Carn Fawr
Carn Enoch
Carn Siffle
Carn Edward
Carn Inglo Cumpen
Carn Fychan
Carn Ingli
Carn Ingli Common
Foel Drygarn
Mynydd Dinas
Mynydd Llanllawer
Mynydd Melyn
Dinas Head
Dinas Island
Pwll Gwasted
Brynhenllan
Dinas Cross
Pwlch Mawr
Aber Ffrenig
Aber Pilipper
Aber Gwaun
Aber Bychan
Aber Bargoed
Aber Felin
Newport
Pen y felen
Pen Rhiw
Llanllawer
Pen y Caer
Rhos y Caerau
Parc Mawr
Parc Gwyn
Parc Cerrigog
Parc Edward
Manorowen
Pen y Caer
Llanwnda
Llanwnda Common
Mal Gwyn Fach
Mal Gwyn Fawr
Rhos Fawr
Rhos Fach
Llanwnda Common
Llanwnda Common
Llanwnda Common







F. H. Mitchell del. et lith. Mintern Bros. imp.

FELSITES, DOLERITES, AND VARIOLITES.
FROM PEMBROKESHIRE.

enabled the beds to be correlated with those at Abereiddy Bay. The observations made by the Author on the igneous rocks, which form so marked a feature in this area, were also highly interesting.

Prof. Hull also spoke.

The Author, in returning thanks for the manner in which his paper had been received, said that, with respect to Dr. Hicks's remarks on the character and thickness of the Middle Llandeilo Beds, he held that they were partly faulted out in this area, and probably in addition were attenuated. The occurrence of large masses of intrusive rock on their horizon had also caused considerable alteration in them; and their calcareous development in Abereiddy Bay did not prepare one for the sandy character which they assumed near Fishguard.

17. *The* Formation *of* Oolite. By E. B. Wethered, Esq., F.G.S., F.C.S. (Read January 9th, 1895.)

[Plate VII.]

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II. Forms of Oolitic Granules	197
III. Origin of the Crusts around the Nuclei	201
IV. Process of Formation of Oolitic Granules	204

I. Introduction.

If a thin section of oolite be mounted in Canada balsam and examined under a microscope, it is seen to be made up of a number of granules associated with fragmental remains of calcareous organisms, and the interstitial spaces are filled in with calcite.

Looked at with a 2-inch object-glass these oolitic granules show, for the most part, a series of concentric strata or laminæ of calcium carbonate around a nucleus. There are also other secondary structures, the principal of which are dark striæ and patches, the former placed more or less at right angles to the nucleus.

At the Bath meeting of the British Association in 1888 Prof. H. G. Seeley read a paper 'On the Origin of Oolitic Texture in Limestone Rocks.' In this communication the author stated that he 'believed that oolitic texture might originate in many ways.....' He also drew attention to the 'close resemblance of the internodal grains of the nullipores to grains of oolite as furnishing a further explanation of oolitic texture. These grains show a concentric structure as well as a radiated tubular structure, which would favour the recrystallization such as commonly occurs.'[1]

Generally speaking, up to the year 1889 the concentric layers were supposed to be chemically deposited calcium carbonate. Thus Dr. Sorby, F.R.S., in his most able and memorable address to the Geological Society in 1879, describes the formation of normal Jurassic oolitic grains in the following words: They are 'composed of more or less well-defined layers of small crystals of calcite..... These crystals are of such an uniform size, both in the same and in different grains, and so definitely oriented, that I can scarcely attribute them to the recrystallization of aragonite, and must conclude that oolitic grains of this type indicate the original deposition of calcite round nuclei gently drifted along by currents of the ordinary temperature, which caught up more or less of the surrounding mechanical impurities.'[2]

In the year 1889 I happened to have under examination some pisolite from the neighbourhood of Weymouth, kindly sent me by Mr. H. B. Woodward, F.G.S. I then discovered that the concentric

[1] Rep. Brit. Assoc. 1888 (Bath meeting), pp. 674 & 675.
[2] Quart. Journ. Geol. Soc. vol. xxxv. (1879) *Proc.* p. 75.

layers were really made up of very minute tubules, which I identified as the little-understood and obscure organism *Girvanella*.

This discovery was communicated to the Geological Magazine in a paper on 'The Microscopic Structure of the Jurassic Pisolite.'[1] Since then I have communicated several papers to the Geological Society in which the origin of oolitic granules has been touched upon; and I have shown that not only are the pisolites formed by the growth of *Girvanella*-tubules around a nucleus, but that some of the smaller, or true, oolitic granules have a like origin. Further, I have myself long entertained, and privately expressed the opinion that oolitic granules in general are of organic origin, but up till now I have not been in a position to prove this. The radiating structure and the apparently endless concentric layers were features which I could not explain. My failure to arrive at the truth was due to a mistake which most of us are liable to fall into; it is that, when we examine a number of similar objects under a microscope, our attention is naturally directed to what we consider to be the most perfect specimens. Thus, in the case of oolitic granules, we select for examination those in which concentric layers are best defined. The less interesting granules, in which the concentric structure is only partially seen or is absent, are liable to be disregarded. I shall, however, show that they are really the most interesting, as affording evidence which enables us to arrive at the origin of the granules.

II. Forms of Oolitic Granules.

In Pl. VII. fig. 1 is represented what I may term the simplest form of granule. The object occurs in a slide of Carboniferous Limestone collected near Buxton, and was given to me by Mr. Edward Wilson, F.G.S., Curator of the Bristol Museum.

In the centre of the granule is a nucleus consisting of an aggregation of *Girvanellæ*, and this is enclosed by a crust. The *Girvanella*-tubules appear in section; that is to say, they have been sliced through in the process of grinding down the slice of limestone. Thus on either side of each tubule we see a thin dark line which represents the calcareous wall, but the central portion is quite transparent, owing to the fact that on the decay of the organic matter the tubules have been filled in with calcite.

Coming to the crust around the nucleus, it is seen to be made up of clear and dark irregular laminæ concentrically arranged around the nucleus, and my object is to determine whether this crust is of organic or inorganic origin.

Some light is thrown on the matter by the object marked A (Pl. VII. fig. 1). There we have a long tubule-like body bounded on either side by a thin dark line, and the interstitial space is transparent. This object, then, resembles the *Girvanellæ* in the nucleus, except that it is much more extended and has a decidedly concentric growth. In parts of the crust similar objects are to be seen, but in

[1] Geol. Mag. 1889, p. 196.

other portions they are not so clearly defined—owing to the tubules not having been cut through, and the massing together produces a compact crust.

My interpretation of the origin of this crust is that it has been constructed by tubular forms of growth allied to *Girvanella*. The transparent tubules are those which have been cut through in making the preparation, thus exposing the infilling calcite in the interior.

The dark portion represents tubules which have not been cut through, and consequently the dark walls remain and when massed together give the appearances represented in the less clearly defined part of the crust.

It is important to notice the irregular growth of the *Girvanellæ* in the nucleus of Pl. VII. fig. 1. Some are seen in tangential, some in vertical section. The same thing occurs in the crust. Some of the tubules grow concentrically, others crop up among the latter more or less at right angles, and are marked by transparent oval spots.

I have dwelt on the features exhibited in Pl. VII. fig. 1 at some length, because they have an important bearing on some of the other granules to be referred to in the course of this paper.

Pl. VII. fig. 2.—This object may be taken to represent a well-defined oolitic granule of the type usually figured in text-books, and, looked at apart from the evidence drawn from other more clearly defined granules, we should hesitate to affirm its organic origin.

In the centre is a nucleus of some kind. This is immediately surrounded by granular amorphous calcareous material and then by concentric strata, the whole being finally encircled by a thin stratum resembling somewhat the tubules which enclose the nucleus in Pl. VII. fig. 1. The other strata are well marked, and are for the most part clear. They are, however, traversed by dark striæ and patches which radiate more or less at right angles to the nucleus.

At the point C there is a break in the concentric arrangement, and it is impossible to resist the conclusion that these appearances are due to intersected tubules. But in some of the concentrically formed granules the strata are masses of growth the outlines of which have been obliterated, and this may be the case in the granule before us.

The next object (Pl. VII. fig. 6 *a*) is representative of a common form of granule of the type also represented by fig. 5. In one part the crust surrounding the nucleus shows a clearly-defined concentric structure, but this to a great extent disappears in the other portion. The first question to be considered is whether this latter feature is caused by obliteration of the original structure or from a difference in the arrangement of the structure forming the crust. The second question is whether the crust is of organic or inorganic origin. The concentric structure is not suggestive of chemically-deposited layers of calcium carbonate, but rather of organic growth, and if this were not continuous in the same plane, then the fact would account for

the disappearance of the clearly-defined concentric arrangement. On the other hand, it is possible that the concentric arrangement, if it ever existed, has been obliterated by molecular changes.

The illustration, Pl. VII. fig. 6 *a*, is drawn from a positive photograph, and represents the object as it appears when examined by transmitted light. When the granule is viewed by reflected light the dark portion in fig. 6 *a* appears white slightly tinged with yellow, and the remaining portion of the object is clear, but not crystalline. These features are well illustrated in Pl. VII. fig. 6 *b*, which is drawn from a negative photograph and represents the object as seen by reflected light.

It is, then, evident that the granule is made up of calcium carbonate existing in two forms: (1) the non-crystalline clear, representing the organic portion of the original granule, and (2) the dark granular, which is really amorphous calcium carbonate (ordinary carbonate of lime), and is either infilling or secreted material, possibly both. In other words, the 'clear' represents the walls or skeletal structure of the organisms forming the granules; and the granular has either been secreted by these organisms, as in the case of the calcareous algæ, or has filled in spaces left by the decomposition of the living matter.

Pl. VII. fig. 5 shows a type of granule somewhat similar to the last-described. In this granule a portion of the crust exhibits concentric laminæ dotted with numerous more or less oval spots. In the remaining portion the concentric arrangement disappears, and we have a mass of dark[1] openings or spots, surrounded by a clear form of calcium carbonate, the former suggestive of infilled organic structure.

Pl. VII. fig. 7.—This granule differs from any that I have previously discussed. There is a central nucleus of some sort enclosed by a crust devoid of laminated concentric structure, nor is there any sign of such a structure having ever existed. It cannot, therefore, be said that granules of this type have originated from chemically-deposited concentric strata.

Pl. VII. fig. 3.—This is a very remarkable type of granule. In the centre is the usual nucleus, the original nature of which is not clear. At first, this is surrounded by an inner crust, which in part shows an obscure mixture of concentric and radiate structure. In some parts the structure is wholly radiate, and among this the outlines of tubules are visible having the appearance of striæ at right angles to the nucleus.

The inner crust terminates in a very irregular concentric growth. At two points the laminæ diverge considerably, leaving spaces which are filled in with amorphous calcium carbonate. Next, an outer crust appears, also made up of irregular concentric laminæ.

As in previous examples of granules, the calcium carbonate is

[1] White, with a tinge of yellow, by reflected light.

present in two conditions, namely, the granular amorphous, representing infilling or secreted material; and the non-crystalline clear, indicating the organic or structural portion of the granule.

One interesting feature in this granule is that the inner and outer crusts are quite independent. At first this granule consisted only of the central nucleus and the inner crust, and in this condition appears to have undergone a certain amount of erosion, evidence of which we get in the two depressions at the top. After a time this inner granule became a nucleus for the outer crust, which seems to have commenced by one or two tubules attaching themselves to the inner crust, and finally developing into the irregular concentric laminated growth represented by the outer crust.

I cannot leave this granule without pointing out how inconsistent the irregularity of the laminæ in the crust is with the chemical theory of the formation of oolitic granules. We can scarcely imagine that deposited strata of calcium carbonate could assume the irregularity and general appearance which this presents. On the other hand, the features are consistent with the growth of such low forms of life as the calcareous algæ.

Pl. VII. figs. 4 *a* and 4 *b*.—These illustrations represent a section of a granule looked at end-ways; fig. 4 *a* is drawn from a positive photograph, fig. 4 *b* from a negative.

Signs of concentric structure are present at the top and bottom of this granule, but the main portion of the crust shows a radiating structure. Around the nucleus there are patches of amorphous calcium carbonate which extends into the radiating structure, and is either concretionary or infilling-material. This is best seen in fig. 4 *b*.

Pl. VII. fig. 8.—This is a form of granule met with in the Coralline Oolite. In the centre are masses of minute tubules which are recognized as belonging to *Girvanella*. Some of these appear in horizontal section, some in vertical. Each one is defined by a dark wall on either side, and the centre is filled in with light and dark material. This aggregation of inner tubules forms a nucleus for a crust wherein occur tubular objects which exactly resemble the *Girvanella* in the centre of the granule, except that they are larger and grow concentrically. There are also spaces in which no structure is visible.

In support of the view that these concentrically growing objects are tubular forms of growth, I would point out that each is bounded by walls, and that the interiors are filled in with light and dark material, precisely as we find the case to be with *Girvanella*-tubules. It may be argued that these objects are organic bodies which have been enclosed by an inorganic crust, and in support of this the fact that the growth is not continuous may be cited. In answer to this objection I would say that at one point the outlines of tubules are visible, though very indistinct. This is evidence of the obliteration of these frail objects, which would

explain the want of continuity and the consequent vacant spaces which occur. It is, however, possible that some of the structureless material present may be secreted; but if so I regard this process as due to the organic element acting in some such manner as the secreting-algæ. Had the tubules been enclosed by inorganic substances they would be irregularly placed, but this is not the case; though there are vacant spaces, yet there is definite concentric order.

Pl. VII. fig. 9.—This, too, is a type of granule not unfrequently met with, and it is also interesting because of the molecular changes which appear to have taken place. The nucleus has lost all trace of structure, and it is surrounded by a fibrous crust showing concentric growth here and there. This crust is finally surrounded by a distinct tubular form of growth, well illustrated at the point B, where a large tubule terminates, and from beneath it three others crop up in succession, ending in circular spots which are really sliced faces of tubules.

III. Origin of the Crusts around the Nuclei.

Under the head of 'forms of oolitic granules,' I have here and there touched upon details which might well have been discussed under the present heading. This could scarcely be avoided under the circumstances, but I have, as far as possible, spared repetition.

It is, however, plain that all the granules to which I have referred cannot have been formed by *Girvanellæ*. As I have before pointed out, the tubules belonging to this genus are enclosed by dark walls, but in the case of granules of which Pl. VII. figs. 3, 4, and 6 are types, the forms of growth are 'clear' but non-crystalline, and there are no dark walls apparent. We have, then, two distinct types of granules before us. There are probably cases in which the dark walls of *Girvanellæ* have been replaced by calcite, but I am disposed to regard the two types of granules under consideration as originating from distinct forms of growth, and not from the mineralogical changes.

With regard to the granules represented in Pl. VII. figs. 1 and 8, I have already described them so much in detail that I need only sum up my conclusions as to the origin of these two. They have been formed by the growth of low tubulated forms of life closely allied to *Girvanella*.

The origin of the crusts represented in Pl. VII. figs. 3, 4, and 6 is more complicated. With regard to fig. 6, a portion of the crust has a very tubulated appearance, but this is not continuous, a fact which makes it evident that the granule is not a concretion. Had this been the origin—that is to say, had the nucleus been enclosed by concretionary layers of calcium carbonate—then the concentric layers should be seen in all parts of the section, no matter in what direction the granule had been cut through. This is not the case in the granule before us. It may be argued that this structure

was continuous, but that it has been destroyed. Of this there is no proof. What evidence there is as to the origin of the crust leads to the inference that the granule has been formed by tubules growing round a nucleus without any system of regularity. In support of this contention I would draw attention to the outlines of tubules in the non-concentric part of the crust, and to the fact that these 'crop up,' as it were, and do not run around the nucleus in the same concentric system as those in the other part.

I have before referred to a feature remarkably well illustrated in Pl. VII. fig. 6 (*b*), namely, that the calcium carbonate in oolitic granules where the concentric layers are 'clear' is usually present in two forms, namely, the granular amorphous and the non-crystalline clear, the latter representing the actual structure, and the former infilling or secreted material. This is inconsistent with the concretionary theory of the origin of oolitic granules. If this latter process were the true one, then the calcium carbonate would be present in the form of ordinary carbonate of lime, which the amorphous substance really is. Doubtless molecular changes have taken place, but these would not explain the condition of things in fig. 6, nor in any of the others that I have examined. I have noticed no disposition of the amorphous calcium carbonate to alter even into calcite. If we take Pl. VII. figs. 4, 6, and 9, the secreted or infilling carbonate of lime shows distinct differentiation, and there is no sign of transition into calcite nor into the fibrous structure which is so characteristic of the granules (fig. 9).

Much of what I have said with regard to fig. 6 applies also to fig. 4, but the difficulty of assigning the origin of the granule to chemical concretion seems to me to be increased. Here we have an oolitic granule which shows concentric lamination in part of the crust; but half is devoid of this feature, and in place of it we see a mass of more or less oval spots surrounded by non-crystalline clear[1] calcium carbonate.

The concentric laminæ are also studded with spots which must have a meaning, as they occur, in some form or other, in most oolitic granules, no matter from what geological formation the oolite may be taken.

Further, it cannot be doubted that there is some connexion between these spots in the concentric strata and those in the non-concentric part. I think, too, that any impartial observer would admit that the dark portion is very suggestive of the infilling by inorganic material of organic structure, the surrounding semi-clear calcium carbonate representing the skeletal structure.

This view, expressed of the organic origin of the granule in Pl. VII. fig. 5, is supported by fig. 7. The structure exhibited by this latter granule is strikingly like the non-concentric part of the former one; in fact, had fig. 5 been cut across the non-concentric part, then we should have had a structure similar to that shown in fig. 7. If we admit, which I think we must, that the last-mentioned

[1] As seen by reflected light.

granule is not a concretion, that is to say, has not been formed by the deposition of concentric strata of calcium carbonate around a nucleus, neither can we conclude that the granule shown in fig. 5 is a concretion.

Some further light is thrown on the spots in the concentric strata by Pl. VII. fig. 9. As I pointed out when describing this granule, a large tubule terminates at B and an oval-shaped section of the face is exposed. Had there been a succession of such tubules cropping up one over the other, then the sliced faces of these would resemble the more or less oval spots in the concentric strata in fig. 5.

To sum up my views as to the origin of the spots or openings in the concentric and non-concentric portions of granules:—In the concentric layers I regard them as the sliced faces of tubules cropping up one over the other, and in the non-concentric as the same, only seen in plan. The two positions in which they are seen seem to arise from the irregular manner of growth.

I have pointed out that there are inconsistencies between the tubular growth in Pl. VII. figs. 1 and 8, and figs. 3, 5, and 7. In the former the tubules are enclosed by dark walls and filled in, for the most part, with calcite. In the case of figs. 3, 5, and 7 the tubules are clear, though non-crystalline, by reflected light, while they have a somewhat milky appearance by transmitted light, and some of the infilling-material is amorphous.

In further explanation of this, I repeat that I do not say that all the forms of growth which I believe have contributed to the formation of oolitic granules are identical with *Girvanella*. There are probably many varieties of oolite-forming organisms. Again, molecular changes do take place in fossil organic calcareous structures. For example, take the stromatoporoids or the sponges. Prof. A. H. Nicholson observes,[1] with reference to the former, that in some instances the skeleton is gradually dissolved and is replaced by crystalline carbonate of lime. That a change of this nature may have taken place with regard to the calcareous portion of the tubulated growth in oolitic granules is not impossible, and indeed seems to find confirmation in the case of Pl. VII. fig. 9. In this granule the larger tubule at A is traversed at right angles by minute needle-like crystals of calcite, and this form of crystallization probably explains the fibrous appearance in the inner crust; that is to say, the calcium carbonate composing the walls of the tubules has been changed into fibrous crystals of calcite.

I now come to the radiate structure which is so marked a feature in the crust of oolitic granules. I confess that the cause of this has been a difficult problem to solve, and it was long before I could bring myself to accept the solution which evidence seemed to dictate. I feel sure, however, that the explanation which I am about to give is at any rate a partial explanation, but it is possible that crystallization may also be a contributing cause.

[1] Palæont. Soc. vol. xxxix. (1885) 'Monogr. Brit. Stromatop.' p. 31.

In Pl. VII. fig. 4 we see the radiating structure in the thin crust around the nucleus, together with concentric growth at both ends of the granule. There is also a number of infilling or secreted calcium carbonate-patches around the nucleus. Now it is certain that this calcium carbonate extends, as it were, into the actual crust and gives rise to the dark striæ which occur.

In Pl. VII. fig. 3 we get a remarkable combination of the radiate and concentric structure.

The radiate structure has the appearance of light and dark striæ when seen by transmitted light. The light striæ are calcitic, and are really tubules which have grown at right angles to the nucleus.

The dark striæ have a different origin, and are secondary formations. To explain this I must again call attention to the patches of amorphous calcium carbonate in touch with the nucleus. Now, there can be no doubt as to the origin of this form of calcium carbonate in the granule. It is either infilling or secreted. Further, this same calcium carbonate extends into the crust; some of the dark striæ can be traced to it, and those cannot which are found to be composed of the same substance. We are therefore justified in drawing the inference that the dark striæ are infillings or secretions.

Such is the conclusion at which I have arrived, and the explanation is the following. I have stated, and must repeat, that the true radiate structure is due to tubules growing more or less at right angles to the nucleus. Some of these have been filled in with amorphous calcium carbonate and appear dark. In other cases the surrounding walls of such tubules have been sliced during the preparation of the slide, thus exposing the infilling material; in some instances this, too, has been partially rubbed away and is represented by a mere film. But the chief cause of the dark striæ, which are sometimes very irregular, is the infilling of interstices between the true striæ.

The appearances justifying the explanation which I have given are not plainly seen in all granules; it is only in a few that the real structure can be determined. Nor is this to be wondered at, when we consider how frail and small are the tubular structures which appear to make up the crust in oolitic granules. It is only when the tubules have been filled in that the outlines are preserved. When infilling has not taken place, the tubules are so pressed together that it is exceedingly difficult, and sometimes impossible, to trace them.

IV. Process of Formation of Oolitic Granules.

Dr. Rothpletz attributes the origin of oolitic granules of the Great Salt Lake to lime-secreting fission-algæ.[1] In the preceding pages I have frequently suggested that the amorphous calcium carbonate which is present in the granules is distinct from the

[1] 'American Geologist,' vol. x. (1892) p. 280; transl. F. W. Cragin from 'Botanisches Centralblatt,' no. 35, 1892.

structural portion and is either secreted or deposited material, probably the former. Seeing then that the oolitic granules of the Great Salt Lake and the Red Sea [1] have originated from the growth of lime-secreting algæ, it is possible that the fossil forms have a like origin.

I do not, however, wish to commit myself by saying that the apparently tubulated forms of growth in oolitic granules are allied to the algæ. This may be so, but, on the other hand, they may be even lower in the scale of life. *Girvanella* is the first type of oolite-forming organism discovered, and is simply a tubule.

The exact process of formation seems to be this:—Minute fragments of remains of calcareous organisms, such as corals, polyzoa, foraminifera, crinoids, etc., collected on the floor of the sea. These became nuclei to which the oolite-forming organisms attached themselves, gradually building up a crust. Sometimes this growth was concentric, sometimes at right angles to the nucleus, or the two combined. When the growth was concentric other tubules frequently cropped up in other directions and crossed the concentric tubules. At the same time calcareous material was secreted, and the interstitial spaces between the tubules were filled.

The explanation of the formation of oolitic granules which I have thus given is simple, and much more reasonable than to suppose that they originated from chemical deposition of concentric strata around a nucleus in the open sea, a condition of things contrary to what is possible according to our present knowledge of the laws of chemical combinations or precipitations.

I cannot, moreover, refrain from pointing out the great interest and beauty of the process of formation of oolitic granules by the growth of such low forms of life as the calcareous algæ—a work so simple, yet so vast.

EXPLANATION OF PLATE VII.

Fig. 1. Oolitic granule from the Carboniferous Limestone near Buxton. The nucleus consists of an aggregation of *Girvanellæ*, and the encircling crust is surrounded by tubular forms of growth of organic origin. × 65 diam.

2. Oolitic granule from the Forest Marble near Cirencester. × 65 diam.

3. Oolitic granule from the Forest Marble near Cirencester. This shows two distinct stages of growth. × 65 diam.

4, *a* & *b*. From the Forest Marble near Cirencester. The first of these is drawn from a positive photograph, and shows the object as seen by transmitted light. The second (4 *b*) is drawn from a negative photograph, and the granule appears as seen by reflected light. The object of the latter illustration is to show the infilling or secreted nature of the amorphous calcium carbonate, which appears white, as against the actual structural portion of the granule, which is dark. In the positive illustration (4 *a*) the colours are reversed. × 65 diam.

[1] *Op. supra cit.*

Fig. 5. Oolitic granule from the Coralline Oolite, Weymouth. The upper portion of the crust shows concentric arrangement, which gradually terminates towards the lower portion, and is finally replaced by a confused mass of dark spots surrounded by calcite. These are assumed to be the filled-in openings of organic structure seen in plan. Similar spots occur in the concentric structure, and are regarded as the same, only sliced in section. ×65 diam.

6, *a* & *b*. From the Forest Marble near Cirencester. The first (*a*) is a reproduction from a positive photograph; *b* is the same object as it appears in a negative photograph. As in the case of fig. 4, the intention is to illustrate that the granule is made up of calcium carbonate existing in two conditions, namely the 'clear,' which is dark in the negative picture and light in the positive, and the 'granular amorphous' condition, which in the positive illustration is dark and in the negative white.

The 'granular amorphous' calcium carbonate is regarded as infilling or secreted material, and the 'clear' in the positive and dark in the negative as representing the organic structural part of the granules. ×65 diam.

7. From the Coralline Oolite near Weymouth. This is a type of granule in which no concentric limestone is apparent. The structure is similar to that in the non-concentric portion of fig. 5. ×65 diam.

8. From the Coralline Oolite near Weymouth. This granule shows a mass of minute *Girvanellæ* surrounded by a crust of concentrically-growing tubules with distinct walls. ×65 diam.

9. From the Forest Marble near Cirencester. This granule has undergone considerable mineralogical changes. The dark portion is 'granular amorphous' calcium carbonate, which is either secreted or infilling material; this has not changed. The 'clear' portion represents the organic structure, and in places this has been converted into minute needles of calcite at right angles to the irregular concentric growth (see A). ×65 diam.

10. This figure is not referred to in the text: it is a granule from the Carboniferous Limestone near Buxton, and is in all respects of similar origin to that shown in fig. 1, namely, the growth around a nucleus of tubular bodies of organic formation.

Discussion.

The President congratulated the Author on the excellent manner in which he had put the subject of the paper before the Society. Whether he had established the organic origin of oolitic granules generally, or had not, he had at least placed the material upon which his views were based most admirably upon the screen. He (the President) had studied orbicular calcite in rocks and in fossil organisms, and had often believed that he was dealing with organic structures, whereas they were only concretionary. He thought that the Author had placed evidence before the Meeting sufficient to prove the organic origin of many of his oolitic granules.

Mr. G. F. Harris thought that this was a very valuable contribution to our knowledge of the origin of oolites; but while most geologists would possibly agree as to the organic nature of the tubules in the pisolites referred to, he believed that they would not be unanimous in recognizing the tubular structure in many of the oolitic granules shown. If the concentric lineations exhibited by

these latter really were tubules, it was remarkable that we observed so few of them in transverse section, seeing that they must necessarily have been cut at random in the preparation of the microscope-slides. He did not at that juncture intend to discuss the origin of oolite, as he felt that there was still much to be learnt concerning the structure of oolitic grains both in the rocks and of recent formation. The oolitic sand now forming in the Bahamas undoubtedly had tubules, as had been previously pointed out by Prof. Judd. Many of the features presented by oolitic granules, and brought forward by the Author as evidence of the organic origin of oolite, could be explained by the alteration effected in them since their original formation. He did not say this in disparagement of the Author's work, for he was much impressed with the profound research displayed, the general excellence of it, and the conclusions to which it had led him. A few days previously he (the speaker) had demonstrated the existence of tubules in certain recent oolitic granules from the United States. He would remind the Fellows present that many years ago Dr. Carpenter described minute calculi found in horses and other animals, which exhibited the most perfect oolitic structure; but he (the speaker) did not wish at that moment to discuss the origin of these.

Mr. E. T. Newton complimented the Author on his zealous researches into the structure of oolitic rocks; but while agreeing with him that the irregular tubules termed *Girvanella*, and seen sometimes within and sometimes on the outside of oolitic granules, were of organic origin, he thought that the characteristic concentric and radiated structure of oolitic granules was entirely different, and not due to concentric tubules. The work of Rothpletz on the oolite-sand of the Great Salt Lake made it highly probable that this concentric structure also was due to some organism; but this did not seem to be satisfactorily established.

Dr. G. J. Hinde did not think that the Author was right in his interpretation of the concentric layers so common in ordinary oolitic grains as tubular forms of growth. In his (the speaker's) opinion these concentric lines might indicate layers of growth, but they were not in any sense tubules. Dr. Rothpletz had already, in his paper 'On the Formation of Oolite,' in the Botanisches Centralblatt for 1892, declared his opinion that 'the majority of marine lime-oolites, with regular zonal and radial structure, are of plant origin, produced by the lime-secreting capacity of microscopically minute algæ of low position.' The very striking similarity in the microscopic structure of the Great Salt Lake recent oolitic grains (as shown in sections exhibited by the speaker) to that of Palæozoic and later oolites supported Dr. Rothpletz's opinion; and if the algal origin of the former should be confirmed, there could hardly remain any doubt that the latter were similarly derived.

Mr. A. C. Seward expressed himself in agreement with the main contention in reference to the occurrence of organic tubular structures in the oolitic grains described by the Author of the paper. In the case of some of the specimens he suggested that the tubules had

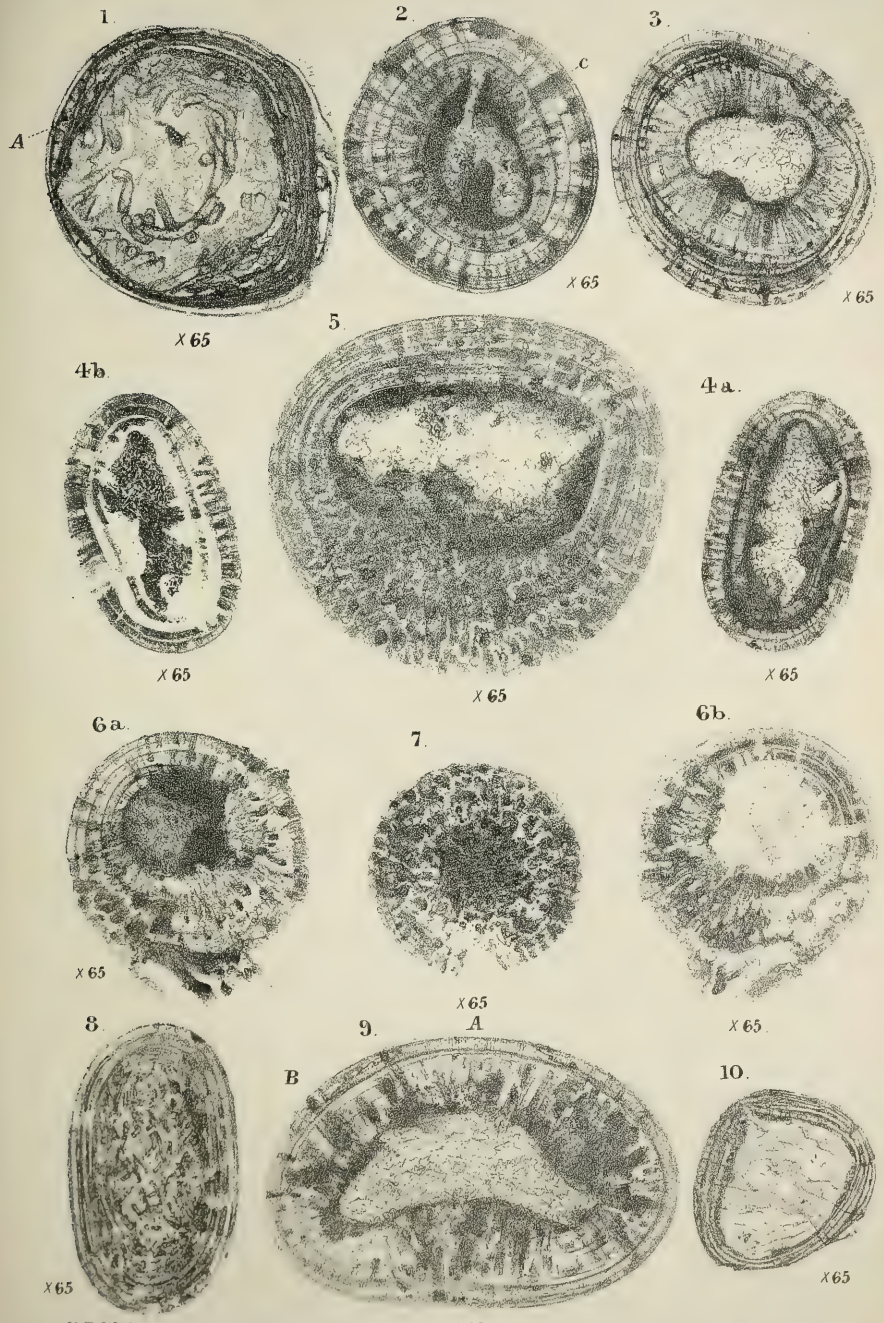
not served as centres for the deposition of carbonate of lime, but had more probably bored their way into the substance of the calcareous nucleus. The explanation offered by the Author with regard to the radiating structure seen in certain grains he regarded as unsatisfactory, their general appearance being much more suggestive of secondary changes in the oolitic grains, which had no direct connexion with the *Girvanella*-tubules.

Prof. Judd said that so far back as 1862 the eminent botanist Dr. Ferdinand Cohn had pointed out the important part played by algæ in the formation of the Sprudelstein of Carlsbad and other calcareous rocks. At a later date Bornet, the eminent French algologist, had insisted no less strongly on the work done in perforation and breaking-up of calcareous fragments by other plants. The speaker, while insisting on the value and importance of the results obtained by Mr. Wethered and other workers in this field of research, was inclined to regard some of the structures (especially certain of the radial ones) as due to the action of destructive rather than to constructive organisms.

Mr. H. B. Woodward referred to the modern formation of oolite-grains in waters charged with bicarbonate of lime, whether in proximity to calcareous springs or coral-reefs. In the Jurassic rocks we find the frequent association of oolite with coral-beds. In the Lower Lias limestone oolitic structure is uncommon, but good examples occur at Applecross in Ross-shire; and it is interesting to note that there the oolitic beds occur in conjunction with bands of coral-rock, while not far away is the remarkably fine coral-bed of Lussay, near Broadford, in Skye. He thought that the slides exhibited by the Author did not show connexion between the *Girvanella* and the concentric and radiate bands of oolite-grains. The carbonic acid abstracted from water during algous growth might, however, lead to the precipitation of carbonate of lime.

Prof. Seeley believed that some of the photographs shown by Mr. Wethered exhibited a structure which, although imperfectly preserved, might be compared with the sections of nullipores which the speaker brought before the British Association at Bath in 1888, as evidence that some grains of oolite are of organic origin. He had been led to that conclusion originally by finding in the Portland oolite polygonal grains such as occur where nullipores branch, and microscopic examination had supported the inference. In the discussion at Bath, Mr. G. K. Gilbert first described the circumstances under which oolitic grains are found on the shores of the Great Salt Lake. And it was interesting that the microscopic structure of those grains, which was subsequently made known, had given similar evidence of organic origin.

Mr. Rutley said that, with regard to the nuclear portions of some of the sections projected upon the screen, he considered that the Author was probably correct in ascribing an organic origin to the interlacing tubular structures; but, so far as the peripheral portion of the oolitic bodies was concerned, he believed that it presented no



E. B. Wethered photogr.
F. H. Michael del. et lith.

Mintern Bros. imp.

SPECIMENS OF OOLITE

appreciable difference from that of ordinary calcareous concretions of a purely inorganic origin : similar radiating and concentric structures being also met with in the spherulites frequently present in eruptive rocks. Difference in the orientation of crystalline grains or fibres might account for some of the appearances which the outer layers of the oolitic bodies exhibited. The later layers, deposited around a nucleus of irregular form, did not necessarily follow the contours of the nucleus.

Prof. A. H. Green also spoke.

The Author thanked the President and Fellows for the way in which his paper had been received. Opinions had evidently undergone some modification since he first appeared before the Fellows, and advocated the organic origin of oolitic granules. The truth of this principle seemed to be now admitted ; but there was difference of opinion on matters of detail. He quite agreed that there was much yet to be done in this direction. He was afraid that he had not made it clear that the concentrically growing tubular forms of growth were not identical with *Girvanella*, though they might be allied to this genus. There were many forms of growth which might be called oolite-producing organisms.

In reply to Dr. Hinde, the Author stated that the sliced ends of tubular forms of growth could be detected, though often with difficulty. This was not to be wondered at considering the frail nature of the organisms, the pressed condition in which they appear in the granules, and the mineralogical changes to which they have been subjected.

18. Notes *on the* Genus Murchisonia *and its* Allies; *with a* Revision *of the* British Carboniferous Species, *and* Descriptions *of some* New Forms. By Miss Jane Donald. (Communicated by J. G. Goodchild, Esq., F.G.S. Read February 20th, 1895.)

[Plates VIII.–X.]

I. The Subdivisions of the Genus Murchisonia and its Allies.

In a previous paper[1] I gave an account of the establishment of the genus *Murchisonia* by D'Archiac and De Verneuil, and described its characteristics. Since that date several new subdivisions of the genus have been made by palæontologists, and however reluctant we may be to introduce new terms, we cannot well avoid doing so, for many of the *Murchisoniæ* vary considerably from the type. Palæontologists differ both in the divisions that they adopt and also in the value that they attach to them. While some merely consider these as sections, others regard them as subgenera, or even distinct genera. Before proceeding to examine these divisions it may be well to enumerate the generic characters of *Murchisonia* as now defined:—

Shell elongated, turreted, composed of more than six gradually increasing whorls. Whorls more or less angular, variously ornamented or smooth. Mouth oblong, oblique, terminated at the base by a very short or truncated canal. Columella arched. In the outer lip there is a narrow and more or less deep slit with parallel edges, the successive filling-up of which during the growth of the shell produces a continuous band throughout the whole length of the spire. This band is distinctly defined, and composed of either a single or double keel. Umbilicus open or closed.

Though D'Archiac and De Verneuil do not indicate any particular species as type, the first mentioned on the list that they give has generally been accepted as such, namely, *M. spinosa*, Goldf. Mr. Whidborne[2] has since shown that this shell is identical with *M. turbinata*, Schlot., and that it is very variable in shape and ornamentation. Some individuals are elongated, others are short and buccinoid; the whorls may be flattened, slightly convex, or decidedly angular. They are generally ornamented by rows of tubercles, but there are numerous intermediate forms showing varying degrees of tuberculation, and merging into perfectly smooth forms. The sinual band is grooved, bounded by two prominent keels, and situated on the angle or widest part of the whorl. I have had the privilege of examining the numerous varieties of this species in the collection of Mr. Vicary, who also kindly gave me

[1] 'Notes upon some Carb. Sp. of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 617.

[2] 'Monogr. Devon. Fauna of the South of England,' part iv. Palæont. Soc. 1892, p. 306.

several specimens. D. and P. Œhlert[1] propose that the name *Murchisonia* should be restricted to tuberculated shells, and suggest the name *Goniostropha* for those which are not tuberculated, but which in other points agree with the type, namely, in the possession of angular whorls with the sinual band situated on the angle, and generally limited by two prominent keels. But this division would hardly be advisable, since some varieties of a single species (as of the type for instance) would be included in *Murchisonia*, and others in *Goniostropha*. D. and P. Œhlert give *M. Bachelieri*, Œhl., as the type of *Goniostropha*, a shell which greatly resembles the smooth variety of *M. turbinata*, with which, indeed, Mr. Whidborne[2] considers it identical. It would be well, however, to limit the name *Murchisonia* to shells having more or less angular whorls with the sinual band situated on the angle or widest part of the whorl, excavated and bounded by keels, or else formed of a single prominent keel; the mouth oblong and slightly channelled below; generally ornamented, the ornamentation consisting of tubercles, plications, or keels. If this be done, some sections or subgenera must be accepted for the forms which differ from this as type.

The name *Hormotoma* was given by Salter[3] to shells distinguished from the typical *Murchisonicæ* by having smooth, rounded, bead-like whorls, with a flat sinual band and a circular mouth. The Silurian *M. gracilis*, Hall, is the type. D. and P. Œhlert retain this section, and suggest the name *Cœlocaulus*[4] for somewhat similar forms which likewise have smooth whorls with a level sinual band, but differ in having the whorls more flattened, the sutures shallower, a narrow but very deep umbilicus, the columella completely vertical, and the peristome reflected. *M. Davidsoni*, Œhl., is given as the type. In addition to these, I have suggested the names *Hypergonia*,[5] *Stegocœlia*,[6] and *Cerithioides* for other sections. The first is characterized by the sinual band being placed above the angle, in other points it resembles the type of the genus. *M. quadricarinata*, M'Coy, is the type of this section. *Stegocœlia* also has the band above the angle, and the umbilicus frequently open when young, but closed by a reflection of the inner lip in the adult. The examination of a larger series of examples has led me to the conclusion that the umbilicus is not always open in youth, but the inner lip is invariably widely reflected on the columella in the mature state. This feature, together with a shorter spire, distinguishes it from the typical *Hypergonicæ*. *M. compacta*, Don., is the type.

I proposed retaining for a section the name *Cerithioides*, originally

[1] Bull. Soc. d'Études Scientifiques d'Angers, 1887, p. 13.
[2] 'Monogr. Devon. Fauna of the South of England,' p. 308.
[3] Geol. Surv. Canada, 'Fig. & Descr. Canad. Organic Remains,' dec. i. (1859) p. 18.
[4] *Op. supra cit.* p. 20.
[5] 'Notes on some New and Little-known Sp. of Carb. *Murchisonia*,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 564.
[6] 'Descr. of some New Sp. of Carb. Gasteropoda,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 623.

given by Prof. Haughton.[1] His type (*C. telescopium*) is a shell characterized by its large conical form, smooth, flattened, and but slightly convex whorls, band not raised above the surface, base flat and grooved, and mouth probably subrhomboidal. The structure of the mouth and base distinguishes it from *Cœlocaulus*.

We have also another group which resembles the typical *Murchisoniæ* in having the band on the more prominent part of the whorl, but which differs in having the band bounded by grooves instead of keels, and in the whorls being more convex. It is distinguished from *Hormotoma* by having the whorls ornamented by bands or threads instead of being smooth, and the mouth is oblong. This section might be called *Glyphodeta*, with *M. zonata*, Don., for the type.

I must here refer to a new subgenus of elongated shells from the Trias of St. Cassian, which Koken[2] calls *Cheilotoma*. He considers it to be more allied to the Alariidæ and Cerithiidæ, with some characteristics of the oldest *Loxonema*, than to *Murchisonia*; but Kittl[3] classes it as a subgenus of the latter genus. It has a sinus in the outer lip which is represented on the whorls by an excavated band bounded by keels: this band is situated above the angle on the lower whorls. Koken states that *C. acutum* has the mouth widened and extended on the spire. According to Kittl, *C. Blumi* also possesses this peculiarity, and he does not attach much importance to it, but considers it a late acquisition. Koken represents the mouth with an anterior canal bent backwards, whereas the figures of Kittl only show such a canal as belongs to the true *Murchisoniæ*. The specimens of *M. Blumi* in the British Museum (Natural History) have a decided canal bent backwards, but not so much as in the figure of *M. acutum* of Koken; they also indicate the spreading of the lip on the spire.

Genera intermediate between *Murchisonia* and *Pleurotomaria*.

Besides the above divisions of the elongated shells referred to *Murchisonia*, I must notice four which appear to be intermediate between *Murchisonia* and *Pleurotomaria*, namely, *Lophospira*, *Worthenia*, *Pithodea*, and *Caliendrum*. The first genus was established by Whitfield[4] for shells whose angular whorls are very closely coiled round the axis, so that the upper whorls are more exsert than usual, the sinus is of greater or less depth, but not necessarily a slit like that of *Murchisonia* or *Pleurotomaria*, the lower whorls have a tendency to become disconnected in the advanced stages of growth, and the columella is always minutely perforated. The second genus was

[1] 'On some Foss. Pyramidellidæ from the Carb. Lste. of Cork and Clonmel,' Proc. Dublin Univ. Zool. & Bot. Assoc. vol. i. pl. iii. p. 282, pl. xx. figs. 2–4.

[2] 'Ueber die Entwickelung der Gasteropoden vom Cambrium bis zur Trias,' Neues Jahrb. Beilage-Bd. vi. (1889) p. 455.

[3] 'Die Gastropoden der Schichten von St. Cassian der Südalpinen Trias,' pt. i. Annal. k.-k. naturhistor. Hofmus. vol. vi. (1891) p. 218.

[4] Bull. Amer. Mus. Nat. Hist. vol. i. no. 8 (1886), p. 311.

created by De Koninck[1] for shells having angular whorls, and the sinual band situated on the angle: this band is also very narrow, and is more or less crenulated, the mouth is polygonal. Kittl[2] enlarges this genus to include some species previously described as *Pleurotomaria*, *Mourlonia*, and *Baylea*, and he also divides it into sections. He states that in the earlier stages of growth the whorls are planospiral, with the exception of the *Triton* group. *Pithodea* was established by De Koninck[3] for the reception of a large buccinoid shell with a wide sinus in the outer lip, which is represented on the whorls by a broad, flat band. The presence of this sinus and band suggests a relationship to *Murchisonia* or *Pleurotomaria*, but De Koninck considers that the extreme thinness of the test distinguishes it from those genera, and he places it among the *Turbinidæ*, although it does not appear to have been nacreous like the shells of that family. This feature separates it also from the typical *Pleurotomariæ*, of which genus Fischer[4] considers it a section. It seems well for the present at any rate to include it in the family Pleurotomariidæ, placing it in proximity to *Murchisonia*, whose test was probably not nacreous.

The name *Caliendrum*[5] was given by Brown to a genus for the reception of a large buccinoid shell, previously described by Phillips as *Buccinum vittatum*. He notes the broad, flat band on the middle of the whorls, but does not observe the deep sinus in the outer lip, the successive filling-up of which gives rise to the formation of this band. Later palæontologists have since referred this shell to the genus *Murchisonia*, from the type of which it differs in having a shorter spire, smooth, rounded whorls, and a flat sinual band bounded by grooves. It agrees with the section *Hormotoma* in its smooth, convex whorls, but differs in being less elongated, in having ventricose whorls, and in the mouth being oval instead of circular. It also bears a great resemblance to *Pithodea*, but is devoid of the lines and grooves with which that genus is ornamented.

These sections cannot all be regarded of the same importance; *Cerithioides*, *Pithodea*, and *Caliendrum*, for instance, show a greater divergence from the type than *Hypergonia* and *Glyphodeta*. At present they can only be considered as provisional, and their exact value can hardly be determined until the whole series of Murchisonoid shells occurring in the rocks from the Cambrian to the Trias is revised. The data on which to found sections are in many cases very meagre, few shells being really well preserved, and the mouth and nucleus are often unknown, so that undue weight is frequently attached to the form of the sinual band, the nature of the ornamentation, and the size. Much importance cannot be ascribed to the latter peculiarity, as a single species varies considerably in this respect. The specimens

[1] Annales Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. viii. (1883) pt. iv, p. 64.
[2] 'Die Gastropoden der Schichten von St. Cassian, etc.' p. 181.
[3] *Op. supra cit.* vol. vi. (1881) pt. iii. p. 88.
[4] Man. de Conch. 1887, p. 850.
[5] 'Illustr. Foss. Conchol. Great Britain & Ireland,' 1849, p. 52.

from the Carboniferous rocks of the West of Scotland, though generally in wonderfully good preservation, are usually very minute. Any classification founded on the ornamentation alone, such as that of Lindström, cannot be considered of much practical value. He divides his Silurian species into two groups, namely, *Simplices* and *Ornatæ*, the first consisting of shells with smooth whorls, whose surface possesses no further ornamentation than that given by the sinual band and the lines of growth; the latter including shells whose surface is more or less richly ornamented. If these divisions were extended, so as to include allied species from other formations, they would certainly not apply, for a smooth variety of a single species would be placed in one group, and an ornamented one in the other.

The groups suggested by Koken are hardly sufficiently distinctive, and there is no apparent advantage to be gained by abandoning names previously given in favour of his. He divides all the *Murchisoniæ* into three divisions, calling them after characteristic species —*Angulatæ*, *Cingulatæ*, and *Cavatæ*. The first name is certainly not advisable, as so much confusion has arisen about the identification of the type species.

Enumeration of Carboniferous Species.

In the most recent list of the Palæozoic Fossils of the British Islands, namely, that of Mr. Etheridge (1888), fifteen Carboniferous species of *Murchisonia* are recorded. They are *M. angulata*, Phill., *dispar*, M'Coy, *elongata*, Portl., *fimbricarinata*, Young & Armstrong, *fusiformis*, Phill., *Humboldtiana*, De Kon., *Larcomi*, M'Coy, *quadricarinata*, M'Coy, *semistriata*, Young & Armstrong, *spinosa*, Phill., *striatula*, De Kon., *sulcata*, M'Coy, *tæniata*, Phill., *Urei*, Flem., and *vittata*, Phill.

In 'Notes on some Carb. Gastr. from Penton and Elsewhere,' Trans. Cumberland and Westmorland Assoc. no. ix. (1883–1884), p. 130, I showed that *Turritella Urei*, Flem., belonged to the genus *Loxonema*, and not to *Murchisonia*, as there is no sinus in the outer lip or band on the whorls, but the shell is ornamented with longitudinal ribs. *M. semistriata*, Young and Armstrong, is referred to the genus *Murchisonia* by mistake, for it is a *Macrocheilina*. *M. striatula* has been placed by De Koninck in the genus *Aclisina*, as it does not possess the characteristic sinus in the outer lip. *M. spinosa* is a doubtful Carboniferous species. Sowerby, in his 'Min. Conch.' vol. vi. p. 125, pl. dlxvi. fig. 2, describes and figures a species of *Murchisonia* as *spinosa* from Bradley, Devonshire, which is of Devonian age. In the 'Pal. Foss.' p. 150, Phillips refers to *M. spinosa* as Carboniferous as well as Devonian, and gives Whitewell, Derbyshire, as the locality for the former. I have examined numerous collections and made a great many enquiries, but have not met with a single Carboniferous specimen agreeing with this species; the name can hardly, therefore, be retained in the list of Carboniferous species.

M'Coy describes two different forms as *M. sulcata*: the first in 1844 in the 'Synops. Char. Carb. Lste. Foss. Ireland,' p. 42, pl. v. fig. 10, which is quite distinct from that described in 1862 in the 'Synops. Sil. Foss. Ireland,' p. 17, pl. i. fig. 20. The type of the former ought to be in the Museum of Science and Art, Dublin, where the Silurian species is, but it cannot be found there. In the 'Brit. Pal. Rocks,' p. 532, M'Coy refers to *M. sulcata* some small shells in the Woodwardian Museum, Cambridge, from Craige, Kilmarnock. Both the figure of the type and these last-named shells are too short to be included with *Murchisonia*, therefore this species cannot be reckoned as a member of that genus.

In the following pages I am about to show that *M. Humboldtiana*, De Kon., is most probably identical with *Pleurotomaria fusiformis*, Phill. It is doubtful whether *Turritella tæniata*, Phill., is a true *Murchisonia*, as the surface of the only specimen is so imperfectly preserved that it does not give distinct evidence of the possession of a sinus in the outer lip. It may be well, however, to retain it in the genus *Murchisonia*, where it has been placed, until we meet with sufficiently good specimens to prove its affinities. The type of *M. Larcomi*, M'Coy, has evidently been mislaid or lost, and the only specimen in the Museum of Science and Art, Dublin, is so poor that it is impossible to make out its characters; therefore I cannot say whether it may not be identical with a species since described. It is difficult to determine these small shells satisfactorily from figures, unless they are very accurately drawn. Thus six species must be deducted from the list, but three previously described shells may be added. *M. kendalensis*, M'Coy, was recorded by Bigsby in 1878 in his 'Thes. Dev.-Carb.' p. 327. *Cerithioides telescopium*, Haughton, is placed both by Bigsby (p. 319) and Etheridge ('Foss. Brit. Islands,' vol. i. Palæozoic, 1888, p. 295) among the Pyramidellidæ, in which family it was originally included by Prof. Haughton. I have since shown that it possessed a sinus in the outer lip, represented on the whorls by a spiral band; it must therefore be classed with the *Murchisoniæ*. *Turritella* (?) *sulcifera*, Portl., recorded both by Bigsby (*op. cit.* p. 335) and Etheridge (*op. cit.* p. 308) in the Turritellidæ, is most probably a *Murchisonia*; though neither mouth nor lines of growth are preserved to indicate the possession of a sinus, it bears a close resemblance to some of the small-keeled *Murchisoniæ*, and it may indeed be identical with one of them, but the only known specimen (the type) is too small and imperfect to admit of certainty upon this point.

There have since been described seventeen additional species and varieties, viz., *M. compacta*, Don., *conula*, De Kon., var. *convexa*, Don., *hibernica*, Don., *Kirkbyi*, Don., *pyramidata*, Don., *pentonensis*, Don., *plana*, Don., *quinquecarinata*, De Kon., var. *pulchella*, Don., *sphærulata*, Don., *subtilistriata*, Don., *tenuissima*, Don., *turriculata*, De Kon., *turriculata*, var. *scotica*, Don., *Tatei*, Don., *tuedia*, Don., *Verneuiliana*, De Kon., and *zonata*, Don. Besides these I am describing in the present paper eleven new species. Thus we have a total of forty Carboniferous forms, or if we exclude *Turritella* (?)

sulcifera, Portl., and *T. tæniata*, Phill., which are doubtfully referred to *Murchisonia*, there are thirty-seven Carboniferous species and one variety (*M. turriculata*, var. *scotica*) referable to this genus. I have not reckoned *Worthenia tabulata* amongst them, as it is probably more closely allied to *Pleurotomaria* than to *Murchisonia*.

In a former paper[1] I pointed out how much confusion has arisen with regard to the identification of *M. angulata* of Phillips, as he has described three different shells under this one name, two Carboniferous and one Devonian. The type of only one of the former is in existence in the Gilbertson Collection in the British Museum (Natural History); it is a mere fragment, and very badly preserved, and M'Coy has since described and figured better specimens of the same form as *M. kendalensis*. Associated with this fossil in the same collection is a portion of a tricarinate shell which I thought might possibly be identical with the other Carboniferous fossil figured by Phillips, but it is clearly not the actual specimen. I then suggested that the name *angulata* might be retained for this shell, but it seems better to abandon the name for a Carboniferous species, more especially as E. Koken[2] considers the Devonian *Turbinites angulatus* of Schlotheim[3] to be a *Murchisonia*. It is not figured, and I have not had the opportunity of examining the original shell myself; but, if Koken's surmise be correct, this form has the priority, and must be taken as the type of *M. angulata*. I therefore propose the name *Gilbertsoni* for the shell described in Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 621, pl. xxiv. figs. 1, 2.

The whole of the forms here enumerated may not ultimately be considered distinct species; moreover some whose mouth and lines of growth have not been clearly discerned may prove to belong to the genus *Aclisina*, but these points can be decided only by the discovery of more numerous and better-preserved examples.

Distribution of the Species in the different Sections.

The species may be thus disposed in the different sections:—In Murchisonia, sensu stricto—*cincta*, *dispar*, *dalryensis*, *fusiformis*, *Gilbertsoni*, *hibernica*, *kendalensis*, *Larcomi*, *Marri*, *pyramidata*, ?*sulcifera*, *subtilistriata*, *Tatei*, *tenuissima*, *Thomsoni*, *turriculata*, *turriculata* var. *scotica*, *Verneuiliana*, and *Youngiana*. These all agree in having the sinual band on the angle or widest part of the whorl; in most it is similar to the type, being excavated and bounded by keels. In four, *dispar*, *Gilbertsoni*, *pyramidata*, and *subtilistriata*, it is not excavated, but is formed by a strong, prominent keel, with occasionally a fine line on each side. It is a question whether these should not be grouped in a separate section. *M. kendalensis* has the band on the higher whorls excavated and

[1] 'Notes upon some Carb. Sp. of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 621.

[2] 'Ueber die Entwicklung der Gastropoden vom Cambrium bis zur Trias' Neues Jahrb. Beilage-Band vi. (1889) p. 369.

[3] 'Die Petrefactenkunde,' Gotha, 1820, p. 164.

bounded by keels, and on the lower ones solid, flat, and bounded by grooves; it thus forms a connecting-link with the section *Glyphodeta*, where, however, the whorls are more convex, and the band uniformly solid and bounded by grooves. *M. dalryensis* differs in having the band formed by three fine keels placed close together. In *M. turriculata* it is doubtful whether the sinual band is formed of a single keel placed on the angle, or whether it lies below the angle and is bounded by a keel on each side. It is convenient, however, to place it in this section for the present. *M. fusiformis* is the species which most resembles the type (*M. turbinata*, Schlot.), especially those forms which have the keels bounding the sinual band undulating as shown in pl. xxix. figs. 8, 9 of the 'Monograph of the Devonian Fauna, etc.' pt. iv. Pal. Soc. 1892; the plications here take the place of the tubercles, while *M. Verneuiliana* comes very near the smooth varieties, *ibid.* pl. xxx. figs. 5–10.

In Hypergonia I would place *conula* var. *convexa*, *deplanata*, *elongata*, *fastigiata*, *Kirkbyi*, *M'Coyi*, *plana*, *pentonensis*, *quadricarinata*, and *quinquecarinata* var. *pulchella*. All these species have the sinual band bounded by keels; it is slightly grooved, and it is also wide, except in *M. elongata*, *M. pentonensis*, and *M. plana*, where it is narrow. *M. conula* var. *convexa*, *M. deplanata*, and *M. plana* have the base flattened, while it is more or less produced in the other species; the mouth of the first is also more rounded than is usually the case. Further discoveries may lead to this section being subdivided.

In Stegocœlia—*compacta*, *variabilis*, and *Smithiana*.

In Glyphodeta—*sphærulata*, *zonata*, ? *tæniata*, and *fimbricarinata*. *M. tæniata* is doubtfully referred to *Murchisonia*, but has most in common with the members of this section, the band which may represent a sinus in the lip being flat and bounded by grooves. *M. fimbricarinata* has slightly more angular whorls than the others, and the band is ornamented by raised crescents.

In Cœlocaulus—? *tuedia*.

In Cerithioides—*telescopium* and ? *Oweni*.

In Caliendrum—*vittata*.

In Worthenia—*tabulata*.

The Carboniferous *Murchisoniæ* are widely distributed, occurring in Britain, Belgium, Germany, Russia, Spain, Carnia, India, Australia, and North America.

Foreign Species of *Murchisonia*.

It is interesting to note the number of species found in other countries, for the sake of comparison with the British species, and it will be seen that the latter are the most numerous.

De Koninck describes twenty-three species in the 'Calc. Carb. de la Belgique,' *M. acuminata*, *acuta*, *amœna*, *angulata*, *Archiaciana*, *Brongniartiana*, *conula*, *deornata*, *gracilis*, *Humboldtiana*, ? *maxima*, *melanioides*, *nana*, *nodosa*, *obesa*, *pertusa*, *plicata*, *quadricarinata*, *quinquecarinata*, *subornata*, *tenuis*, *turriculata*, and *Verneuiliana*.

In his earlier work, 'Descr. des Anim. Foss. Carb. de la Belgique' he gives two, *M. subsulcata* and *M. Sedgwickiana*, which he does not refer to again. It is a question whether the whole of these twenty-five species are really *Murchisoniæ*, for some do not give evidence of having a sinus in the outer lip. In the Woodwardian Museum there are some shells from Settle which appear to be identical with *M. melanioides*, De Kon.; but they are not true *Murchisoniæ* though they have a band on the whorls, for the lines of growth may be discerned coming down over this band without showing any deflection for a sinus. The lines of growth are not distinct on the Belgian specimens of this species in the British Museum (Natural History). Other doubtful *Murchisoniæ* are *Brongniartiana*, *gracilis*, and *nana*, which do not seem to have a clearly defined sinual band. Seven of these Belgian species are most probably represented in Britain: *M. angulata*, De Kon. (non Phill.) by *M. dispar*, M'Coy; *conula* by its variety *convexa*, Don.; *Humboldtiana* by *fusiformis*, Phill.; *maxima* by *telescopium*, Haughton; *quinquecarinata* by its variety *pulchella*, Don., and possibly by *quadricarinata*, M'Coy; *turriculata* and *Verneuiliana* have also been identified; *quadricarinata*, De Kon., is probably a small variety of *conula* var. *convexa*.

Goldfuss ('Petref. Germ.' vol. iii.) records five Carboniferous species of *Murchisonia*, namely, *angulata*, *spirata*, *Josepha*, *trilineata*, and *plicata*, and one species of *Turritella*, which may be *Murchisonia*, namely, *gracilis*. De Koninck considers *T. gracilis* to belong to the latter genus. I have examined the type-specimen: it is small, and I was unable to discern any lines of growth; therefore I am doubtful whether it should be referred to *Murchisonia* or to *Aclisina*. *M. Josepha* is identical with *M. Humboldtiana*, De Kon. *M. plicata* is thought by De Koninck to agree with a shell which he describes under the same name, but it differs in having the keels limiting the sinual band undulating, the keel below the band slightly nodose, a row of small tubercles just below the suture, and the lines of growth so strong as to give the shell a plicated appearance. In all these points it is similar to *M. fusiformis*, Phill., and it may be a young example of that species. Only three of these species are peculiar to Germany, as *M. angulata*, *M. Josepha*, and *T. gracilis* occur in Belgium.

Two Spanish species are given by Mallada ('Sin. de las Especies fosiles,' Bol. Com. Geol. Españ. vol. ii. 1875, p. 103): they are *M. angulata*, Phill., and *M. abbreviata*, Sow. The figure of the former is unlike any of the shells described by Phillips under that name, and the latter is not that of Sowerby, but bears a greater resemblance to *M. abbreviata* of De Koninck, since called *conula* by him.

Eichwald ('Leth. Ross.' vol. i. pt. ii. p. 1180) describes three elongated species of *Pleurotomaria* from Russia, which may be *Murchisonia*, namely, *P. angulata*, Phill., of which he gives only a very brief description and no figure; *P. spirula*, which is very minute, and the sinual band is not described; and *P. carbonaria*, of which

the description and figure are not sufficiently precise for comparison with other species.

Parona (Boll. Soc. Geol. Ital. vol. ix. 1890, p. 56) gives three species from Monte Pizzul in Carnia, viz. *M. angulata*, Phill. & De Kon.; a new species allied to *M. conula*, De Kon.; and an undetermined species allied to *M. nana* and *M. nodosa*, De Kon.

Waagen (Palæont. indica, ser. 13, Salt Range fossils, vol. i. pt. ii. 1880, p. 125) records only one species in India, *M. conjungens*, and it is imperfectly preserved.

In the Catalogue of Australian Fossils (1878), p. 84, R. Etheridge, Jun., gives five Carboniferous species: *M. angulata*, Clarke, *carinata*, Etheridge, ? *tricincta*, Morris, *trifiliata*, Dana, and *Verneuiliana*, De Kon. The first he refers with a query to *M. Verneuiliana*, De Kon.; *M. carinata* is merely a cast; *M. tricincta* is small, and the sinual band is not indicated; and *M. trifiliata* is short and more like *Pleurotomaria*.

There are about twenty-three American species, but two, *M. kansasensis*, Swallow, and *M. perversa*, Swallow, are referred to the genus with a query, and many are not figured, so that it is impossible to compare them satisfactorily with species from other countries. Of those which are figured the following species resemble British forms in certain points, but as they are mostly small they cannot be identified from figures with certainty:— *M. attenuata*, Hall, and *vermicula*, Hall, bear some similarity to ? *Orthonema Youngianum*, Don. *M. Copei*, White, resembles *M. deplanata*, Don., but is distinguished by its greater size and wider spiral angle. *M. nebrascensis*, Geinitz, also differs from *M. Kirkbyi*, Don., in its wider spiral angle, though it resembles it in other respects. *M. turritella*, Hall, is very like *M. quadricarinata*, M'Coy, in the form of the spire, in the position of the sinual band, and in the number of keels with which it is ornamented. *M. terebriformis*, Hall, differs from *M. sphærulata*, Don., in possessing a greater spiral angle and in having stronger and less numerous lines below the sinual band.

In conclusion I must express my gratitude for the facilities afforded me on all sides in the preparation of this paper. Dr. John Young, Mr. James Thomson, Mr. John Smith, and Mr. Joseph Wright have all been extremely kind in lending me specimens; and those in charge of the different public collections have given me every assistance in their power.

II. Description of the Species.

Murchisonia, sensu stricto.

Murchisonia cincta, sp. nov. (Pl. VIII. figs. 1, 2.)

Shell small, turreted, composed of more than eleven whorls. Apex acute. Nucleus consisting of about two whorls, cylindrical, smooth, apical one convex. Whorls rounded, increasing gradually. A wide space about the middle of each whorl, bounded on each side

by a keel, probably represents the sinual band; there are two finer keels below and one above. Lines of growth not discernible. Mouth rounded. Base flattened. Columella nearly straight.

The species which this most resembles is *M. quadricarinata*,[1] M'Coy, but the whorls are more convex, the sinual band is situated on the most prominent part of the whorl instead of above the angle, and the keels limiting it are about equal in strength; besides which the base is more flattened.

The collection of Dr. John Young, Glasgow, contains four specimens of this species: one (Pl. VIII. fig. 1) has eight whorls preserved; it is about 4 millim. in length, and about $1\frac{1}{2}$ millim. in width. I also have portions of two additional shells which Dr. Young has given me.

Locality. Glencart, Dalry.

Formation. Upper Limestone Series (d^3).

Mr. John Smith, Kilwinning, has a single specimen (Pl. VIII. figs. 2, 2 *a*) consisting of twelve whorls; the apex is entire, but the base is slightly broken. Length about $4\frac{1}{2}$ millim., width $1\frac{1}{2}$ millim.

Locality. Law, Dalry.

Formation. Lower Limestone Series (d^3).

Murchisonia dispar, M'Coy. (Pl. VIII. figs. 3–8.)

Murchisonia dispar, F. M'Coy, 1853, Ann. & Mag. Nat. Hist. ser. 2, vol. xii. p. 191; F. M'Coy, 1854, 'Contrib. Brit. Pal.' p. 259; F. M'Coy, 1855, 'Brit. Pal. Rocks and Foss.' p. 531, pl. 3 I, figs. 37, 37 *a*; ? E. Tietze, 1871, 'Palæontographica,' vol. xix. p. 141, pl. xvii. fig. 22; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 325; R. Etheridge, 1888, 'Foss. of Brit. Islands,' vol. i. Palæozoic, p. 301; H. Woods, 1891, 'Cat. Type Foss. in Woodwardian Museum,' p. 107.

? *Murchisonia angulata*, L. G. de Koninck, 1883, 'Faune du Calc. Carb. de la Belgique,' vol. viii. pt. iv. p. 18, pl. xxxiv. fig. 4 (in Annales Mus. Roy. Hist. Nat. Belgique).

Shell elongated, turriculated, composed of more than seven whorls. Whorls angular below the middle, slightly convex above, flattened below, body-whorl produced. Sinual band situated on the angle, composed of a strong and prominent keel with a fine line on each side of it. Ornamented above the band by about six spiral lines; sometimes two are decidedly stronger than the rest, while the two upper ones are generally the finest. Below the band on the body-whorl there are numerous and stronger keels, with one or two fine lines between them; the upper six keels are usually the strongest; only two or three of these keels with the alternating lines are visible on the spire, the rest being hidden below the suture; the space between the third and fourth keels is the widest. Lines of growth fine, curving backwards to the band above and forwards below. Sutures oblique, fairly deep. Mouth longer than wide. No umbilicus. Test thin.

The form which this species most resembles is *M. angulata* of De Koninck, but the specimen figured by him is smooth above the angle, showing no traces of spiral lines; also the angle is higher up

[1] 'Notes on some New and Little-known Species of Carb. *Murchisonia*,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 564, pl. xvi. figs. 3–6.

the whorl than in the type of *M. dispar*. The surface of the Belgian specimen, however, is not well preserved, and the ornamentation above, being finer than that below, would be more easily obliterated, and many of the British specimens show no traces of it, or merely one or two of the stronger lines. Moreover there is some variation in the height of the angle above the suture; therefore I am inclined to consider the Belgian shell a variety of this species. *M. dispar* differs from the shell referred (but with a query) to *M. angulata*, Phill.,[1] in possessing a greater spiral angle, whorls more convex in outline, and more obliquely set, less strong keels, and also in having lines above the band. It may, however, prove to be a variety of that form, of which most of the specimens that I have seen are merely portions of the upper part of the spire. A fragment of a specimen of *M. dispar* (Pl. VIII. fig. 8) in the collection of Mr. J. Wright comes very near that described as *M. angulata*, the keels below the band being stronger than usual, and the surface of the upper part of the whorl not quite so convex. But it is difficult to form a just comparison, as the shell is deformed by pressure. Phillips, in 'Pal. Foss.' p. 150, gives Northumberland as a locality for *M. angulata*, so he may possibly refer to this shell.

E. Tietze considers a Devonian shell identical with this species; he gives no description, and his figure is very small.

In the Woodwardian Museum there are three specimens from Lowick, all small and merely casts, only one of which, the type, shows traces of ornamentation. It is embedded in the matrix, and portions of five whorls are exposed whose length is 13 millim. (Pl. VIII. figs. 5, 5 *a*). There are two larger specimens from the same locality, one in the Museum of Practical Geology, London, and the other in the Newcastle-on-Tyne Museum. The former is a cast, and the latter is but little better; both have the angle rather higher up the whorl than the type.

Formation. Yoredales (d^3).

Other individuals are from the Avon Section, Clifton, ten of which are in the Bristol Museum, three in the British Museum (Natural History), and three in Owens College Museum, Manchester. These agree with the type in having the angle situated low down on the whorl. The largest is in the Bristol Museum: five whorls are preserved, and there are traces of two others; the apex is broken. If entire, the shell would probably consist of about ten whorls. Length of five whorls=43 millim.; width=19 millim. (Pl. VIII. fig. 4.)

In the Woodwardian Museum there are also two casts of this species from Settle. The largest has six whorls preserved, whose length is 53 millim.; width of body-whorl=22 millim.

Four shells from Cork appear to be identical with this species; one is in the Museum, Queen's College, Cork, and the other three are in the collection of Mr. J. Wright, Belfast. They are all more or less compressed obliquely, but the surface is well preserved.

[1] 'Notes upon some Carb. Species of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 621, pl. xxiv. figs. 1, 2.

The band is somewhat higher above the suture than in the type, three keels being frequently visible below it on the upper whorls. Length of specimen figured (Pl. VIII. fig. 3) 25 millim., width 15½ millim.

An external cast in the Oxford Museum, from Osgathorpe, most nearly resembles these Irish specimens, as the angle is situated higher up the whorl. Only five whorls are preserved; length 17 millim., width 8 millim. (Pl. VIII. fig. 7.)

Formation. Carboniferous Limestone (d^2).

MURCHISONIA FUSIFORMIS, Phill. (Pl. VIII. figs. 9, 11, 12.)

Pleurotomaria fusiformis, J. Phillips, 1836, 'Geol. Yorks.' pt. ii. p. 227, pl. xv. fig. 16; T. Brown, 1849, 'Illustr. Fossil Conchology Gr. Brit. & Ireland,' p. 88, pl. xl. fig. 40.

Murchisonia excavata, L. G. de Koninck, 1843, 'Précis élém. de Géol.' par J. J. d'Omalius d'Halloy, p. 516.

Murchisonia Humboldtiana, L. G. de Koninck, 1843, 'Descr. des Anim. Foss. du Terr. Carb. de la Belgique,' p. 410, pl. xxxviii. fig. 1; H. G. Bronn, 1848, Index Palæont. p. 747; A. d'Orbigny, 1850, 'Prodr. de Paléont. strat.' vol. i. p. 122; J. Morris, 1854, Cat. Brit. Foss. p. 259; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 325; L. G. de Koninck, 1883, 'Faune du Calc. Carb. de la Belgique,' vol. viii. pt. iv. p. 14, pl. xxxiii. figs. 47–49; R. Etheridge, 1888, 'Foss. Brit. Islands,' vol. i. Palæozoic, p. 301.

Murchisonia Josepha, A. Goldfuss, 1844, 'Petr. Germ.' vol. iii. p. 26, pl. clxxii. fig. 7; A. d'Orbigny, 1850, 'Prodr. de Paléont. strat.' vol. i. p. 123; C. Giebel, 1866, 'Repertor. zu Goldf. Petr. Deutschl.' p. 93; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 325.

Murchisonia fusiformis, H. G. Bronn, 1848, Index Palæont. p. 747; J. Morris, 1854, Cat. Brit. Foss. p. 259; J. J. Bigsby, 1878, 'Thes. Dev-Carb.' p. 325; R. Etheridge, 1888, 'Foss. of Brit. Islands,' vol. i. Palæozoic, p. 301.

Shell conical, composed of ten or eleven whorls. Whorls angular, strongly plicated in adult specimens, less strongly so in young ones, the plications commencing at the suture, running downwards to the sinual band, and continuing below the band to the lower suture. Sinual band situated on the angle rather above the middle of the body-whorl, and about the middle or slightly below on the upper whorls; bounded by two undulating, moniliform keels, the undulations of which do not exactly coincide; down the middle of each keel runs a fine groove. There is generally an angularity on the body-whorl at a short distance below the band, which appears just above the suture on the upper whorls. The whole surface is covered by numerous fine spiral lines, only visible on well-preserved specimens. Lines of growth fine, distinct, curving backwards to the band above and forwards below, strongly arched on the band itself. Mouth oblong, probably slightly channelled below. Inner lip simple in young specimens, reflected on the columella in adult individuals. Test of medium thickness.

Pleurotomaria fusiformis, Phill., appears to me identical with *M. Humboldtiana*, De Kon. The poor figure and short description in the 'Geology of Yorkshire' have evidently led to this fact being overlooked; also the original specimen is small and much worn, thus

the plications are not so distinct as in larger and better preserved individuals; the characteristic moniliform sinual band is, however, clearly marked.

In the 'Faune du Calc. Carb. de la Belgique,' p. 15, De Koninck states that *M. Humboldtiana* possesses a small umbilicus, and this is represented in the figure of that work, but the figure in his previous work 'Descr. des Anim. Foss. du Terr. Carb. de la Belgique,' pl. xxxviii. fig. 1, shows the inner lip reflected on the columella and covering the umbilical region, and this is the case with the adult Belgian specimens in the British Museum (Natural History). None of the British shells that I have seen show an open umbilicus, but the aperture is not well preserved in any of them. That of the type of *M. fusiformis* is the best, and there the columella appears simple and the umbilicus is closed.

The only Carboniferous species which this form resembles is *M. Verneuiliana*, De Kon.,[1] which is like it in shape, but the band is wider, and it is not moniliform, also the plications are absent. Nevertheless it is sometimes difficult to tell to which species very worn specimens should be referred. One of the shells in the Woodwardian Museum described in a former paper[2] as *M. Verneuiliana* is an example of this, for, as is there noticed, the keels bounding the band are slightly undulating, and the band also is rather narrower than is usually the case. There is no sign of the plications, but the surface of the shell is much worn, which may have caused their obliteration, and also on the other hand have given rise to the undulating appearance of the sinual band.

The type (Pl. VIII. fig. 9) is in the Gilbertson Collection in the British Museum (Natural History). It consists of six whorls, and the apex is broken. Length = 14 millim.; width of body-whorl =about 8 millim.

Localities. The type is from Bolland. Other specimens occur at Settle and Longnor, Staffordshire. From the former place there are three examples in the Woodwardian Museum. The largest (Pl. VIII. fig. 12) has only three whorls preserved, the apex being broken: its length is 16 millim.; width $=11\frac{3}{4}$ millim. Another has part of five whorls whose length is 9 millim. The plications are not so strong on this one. The York Museum also contains a fine specimen from this locality (Pl. VIII. fig. 11); there are five whorls existing, of which the length is 20 millim., width $10\frac{1}{2}$ millim. The largest shell is in the Museum of Practical Geology, from Derbyshire; it has the apex broken, leaving five whorls, whose length is 26 millim. Besides this there are also two small shells from Longnor in the same Museum, and another from the same locality in the Museum of Science and Art, Dublin.

Formation. Carboniferous Limestone (d^2).

[1] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. viii. (1883) pt. iv. p. 25, pl. xxxiv. figs. 35–37.

[2] 'Notes upon some Carb. Species of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 626, pl. xxiv. fig. 6.

MURCHISONIA MARRI, sp. nov. (Pl. IX. fig. 2.)

Shell elongated, turriculated, composed of more than nine whorls. Whorls increasing gradually, slightly angular, rather flattened above, more convex below. Sinual band situated near or a little above the middle of the whorl, narrow, bounded on each side by a moderately strong keel. Ornamentation below the band consisting of three slighter keels, with sometimes a thread between each of them; above the band there are from one to three threads, the uppermost appearing just below the suture, another being about halfway between it and the band, and there is sometimes a third between that and the band. Lines of growth curving backwards to the band above and forwards below. Sutures deep. Mouth unknown.

The species which this most resembles is *M. elongata*,[1] Portl., from which it differs in having a smaller spiral angle, more convex whorls, band situated higher up the whorls, and more numerous keels below the band. It is also somewhat like *Aclisina striatula*, De Kon.,[2] but the lines of growth appear to indicate a true sinus in the outer lip, the upper part of the whorl is more flattened, and the spiral threads are less numerous.

Some external casts of this shell have been discovered by Mr. Marr. The figure is drawn from a wax impression. None of the individuals are entire. Length of that figured (Pl. IX. fig. 2) $=22\frac{1}{2}$ millim.; width $=10$ millim.

Locality. Shap.

Formation. Carboniferous Limestone (d^2).

MURCHISONIA DALRYENSIS, sp. nov. (Pl. IX. fig. 3.)

Shell elongated, turriculated, composed of more than twelve whorls. Whorls somewhat convex, slightly angular about the middle. Upon the angle there are three strong threads of nearly equal strength, placed close together, which probably represent the sinual band. Below this band there are three fine threads, then a space, which is succeeded by a very strong thread appearing just above the suture. Upper half of the whorls smooth. No lines of growth preserved. Sutures not much inclined. Mouth unknown.

This species strongly resembles members of the genus *Aclisina*, De Kon., in the convexity of the whorls and the ornamentation. In spite of the mouth and lines of growth not being preserved, I refer it provisionally to the genus *Murchisonia*—on account of the three threads placed close together being suggestive of a sinual band. Also it is somewhat like *M. subtilistriata*, Don.,[3] from which species it may be distinguished by its less angular whorls, band formed of three threads instead of one strong keel, and the ornamentation being rather different.

[1] 'Rep. on Geol. of Londonderry,' 1843, p. 569, pl. xxxviii. fig. 10*a*, *b*.

[2] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. vi. (1881) pt. iii. p. 86, pl. ix. figs. 57, 58; vol. viii. (1883) pt. iv. pl. xxxiii. figs. 41, 42.

[3] 'Descr. of some New Sp. of Carb. Gasteropoda,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 623, pl. xx. figs. 7, 8.

Mr. J. Thomson, Glasgow, possesses one specimen. It consists of twelve whorls; both apex and base are broken. Length = $8\frac{1}{2}$ millim.; width of penultimate whorl = about $2\frac{1}{2}$ millim.

Locality. Dalry.

Formation. Upper Limestone Series (d^3).

MURCHISONIA THOMSONI, sp. nov. (Pl. IX. fig. 1.)

Shell elongated, turriculated, composed of more than five whorls. Whorls angular about the middle, gradually increasing. On the angle there are two keels placed close together with only a narrow groove between; this probably represents the sinual band. The ornamentation consists of three keels below the band, and two above, the former placed at equal distances from each other and the latter having a wide space between them, one being immediately below the suture and the other a little above the band; there is an additional keel on the body-whorl. Lines of growth not preserved. Sutures oblique. Mouth imperfectly known.

The very narrow sinual band distinguishes this from all other Carboniferous species.

A single specimen of this species is in the collection of Mr. James Thomson. Only five whorls are preserved. Length = $7\frac{1}{2}$ millim.; width = $2\frac{3}{4}$ millim.

Locality. Craigenglen.

Formation. Lower Limestone Series (d^3).

MURCHISONIA YOUNGIANA, sp. nov. (Pl. VIII. figs. 10, 13.)

Shell very elongated, turriculated, composed of more than sixteen whorls. Apex acute. Whorls almost convex, but slightly angular. The lower half of the whorl is ornamented by four keels of about the same strength and separated by nearly equal spaces; above, there is a much slighter keel just below the suture. Lines of growth not visible. Sinual band probably situated on the most prominent part of the whorl, between the two uppermost of the four keels. Base flattened, without additional keels. Mouth oval. Columella simple, nearly straight.

This shell most resembles *Turritella*(?) *sulcifera*, Portl.,[1] but the only known specimen of that species is too small and imperfect for positive identification. It also bears some similarity to *M. pentoncnsis*, Don.,[2] but it is more elongated, the whorls are more convex, the keels more nearly equal in strength, and the spaces separating them of about the same width; there are no additional keels on the body-whorl, and the base is somewhat flattened instead of being produced.

A specimen in the collection of Mr. J. Smith (Pl. VIII. figs. 13, 13 *a*) consists of fifteen whorls; the apex is entire, but the base is broken. The nucleus is convex and smooth, and probably consists

[1] 'Notes upon some Carb. Sp. of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 630, pl. xxiv. fig. 12.

[2] 'Notes on some New and Little-known Species of Carboniferous *Murchisonia*,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 569, pl. xvi. figs. 10–12.

of two whorls. The upper part of the spire is worn, so that it is impossible to say when the ornamenting keels commenced. Length =10 millim.; width =3 millim.

There is another individual in the collection of Dr. John Young (Pl. VIII. fig. 10), consisting of the same number of whorls; the apex is broken, and its length is 9 millim., width $2\frac{1}{2}$ millim.

Locality. Law, Dalry.

Formation. Lower Limestone Series (d^3).

Section Hypergonia, Don.

Murchisonia (Hypergonia) deplanata, sp. nov. (Pl. IX. figs. 8, 10.)

Shell elongated, turriculated, upper part of the spire sometimes slightly convex in outline, composed of more than twelve whorls. Whorls increasing gradually, angular below the middle, flattened both above and below the angle. Ornamented by a strong keel on the angle, another at a distance below, appearing just above the suture on the upper whorls, and one or two very fine lines on the body-whorl below this keel. Above the angle there are two finer keels with a wide space between the lower one and the angle, which probably represents the position of the sinus. Lines of growth strong and distinct, curving backwards above over the two finer keels and forwards below the angle, invisible on the wide space above. Base flattened. Mouth but slightly longer than wide. Columella simple. No umbilicus.

This shell strongly resembles *M. quadricarinata*, M'Coy,[1] and *M. quinquecarinata*, De Kon.,[2] but may be distinguished by having only one keel instead of two below the angle, and that at a considerable distance; moreover the base is much flatter.

Dr. John Young possesses one specimen (Pl. IX. fig. 8). It consists of eleven and a half whorls; the apex is broken; if entire there would be one or two whorls more. I have also two fragments which were given me by Dr. Young. Length =$6\frac{1}{4}$ millim.; width =2 millim.; height of body-whorl =2 millim.

The Armstrong Collection in the Museum of Science and Art, Edinburgh, contains portions of the spires of two individuals. The apex (Pl. IX. fig. 10) of one of these is well preserved: it is somewhat blunt; the nucleus is simply coiled and consists of two or three smooth whorls. Mr. Thomson has a single specimen in his collection, of which only five whorls are preserved, the apex being broken.

Locality. Glencart, Dalry.

Formation. Upper Limestone Series (d^2).

I have also one small specimen given me by Dr. Young from the Lower Limestone Series of Law, Dalry.

[1] 'Syn. of the Char. of the Carb. Limest. Foss. of Ireland,' 1844, p. 42, pl. v. fig. 9.

[2] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. viii. (1883) pt. iv. p. 23, pl. xxxiv. figs. 14–16.

MURCHISONIA (HYPERGONIA) FASTIGIATA, sp. nov. (Pl. IX. fig. 4.)

Shell elongated, turriculated, composed of more than eight whorls. Whorls gradually increasing, convex, slightly angular above the middle, more convex below the angle than above. Sinual band broad, situated above the angle, bounded by a keel on each side with a fine thread down the middle. Three keels below the band on the spire, an additional one on the body-whorl, and one keel above the band just below the suture; space between this uppermost keel and the band the widest. Lines of growth not preserved. Sutures deep and oblique. Mouth longer than wide. No umbilicus.

There is only one specimen of this species in the Museum of Practical Geology, London. It somewhat resembles *M. quinquecarinata*, var. *pulchella*,[1] in shape, but may be distinguished by its more convex whorls and also by the form of the sinual band. The spiral angle is smaller than that of *M. pentonensis*,[2] the sutures are more oblique, and the sinual band is different.

The apex of the shell is broken and only seven and a half whorls remain, of which the length is $16\frac{1}{2}$ millim.; width of body-whorl = 5 millim.

Locality. Clattering Ford, Cumberland.

Formation. Calciferous Sandstone Series (d^2).

MURCHISONIA (HYPERGONIA) M'COYI, sp. nov. (Pl. IX. fig. 5.)

Shell very elongated, turriculated, composed of more than seventeen whorls. Whorls angular, increasing very gradually. Angle a little below the middle of the whorl bearing a strong keel, and having two slighter ones above and two below. The widest space is that between the keel on the angle and the lower of the two above: it probably represents the position of the sinus. Lines of growth not visible. Base convex, columella simple. Mouth imperfectly known.

As neither the mouth nor the lines of growth are preserved, we cannot be certain whether this is a species of *Murchisonia* or *Aclisina*. I refer it to the former on account of its great similarity to other members of the genus, especially to *M. quadricarinata*, both in the form and ornamentation of the whorls; but it is more elongated, having a much smaller spiral angle. It occurs as external casts in an impure limestone, and perfect representations of the shell are obtained by pressing wax into the cavities.

Length of specimen figured (Pl. IX. fig. 5) = 7 millim.; width = $1\frac{1}{2}$ millim.

Locality. Widdle Fell, Wensleydale.

Formation. Yoredales (d^3).

Mr. J. Smith also possesses three specimens of this species. The whorls are not quite so angular; as many as seventeen are

[1] 'Notes on some New and Little-known Species of Carb. *Murchisonia*,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 566, pl. xvi. fig. 7.

[2] *Ibid.* p. 569, pl. xvi. figs. 10–12.

preserved on one individual; the surface is much worn and the apex is broken; if entire there would probably be four or five more whorls. Its length is 8 millim.

Locality. Law, Dalry.

Formation. Lower Limestone Series (d^3).

Section Stegocœlia, Don.

Murchisonia (Stegocœlia) Smithiana, sp. nov. (Pl. X. fig. 3.)

Shell turreted, rather short, composed of more than five whorls. Whorls angular, slightly concave both above and below. Sinual band situated above the angle, broad, raised above the surface of the whorl, somewhat solid, being very slightly grooved, with a fine thread down the middle. Ornamented by two threads above, just below the suture, and one keel below the sinual band, with four additional keels on the body-whorl and a fine thread between the sinual band and the keel next below. Lines of growth fine and distinct, curving back to the band above and forwards below. Mouth oblong, slightly channelled below, inner lip reflected on the body-whorl. Columella nearly straight.

This species somewhat resembles *M. compacta*, Don.,[1] but differs in the form of the sinual band and in having more numerous keels on the body-whorl. The structure of the sinual band also distinguishes it from the intermediate specimens of *M. variabilis*.

The collection of Mr. J. Smith contains a single specimen of this shell. The apex is broken, leaving five whorls, whose length is 5 millim., width about $2\frac{1}{2}$ millim.

Locality. Law, Dalry.

Formation. Lower Limestone Series (d^3).

Murchisonia (Stegocœlia) variabilis, sp. nov. (Pl. IX. figs. 6, 7, 11.)

Shell turriculated, composed of nine or ten whorls. Apex acute. Nucleus consisting of from two to three whorls, smooth, the last sometimes swollen. Whorls angular near the middle or rather below. Ornamentation consisting of a strong keel on the angle with two above and below, and one or two additional keels on the body-whorl, the uppermost keel being generally the finest and occasionally absent. Lines of growth not preserved. Sinual band probably situated above the angle, between the keel on the angle and that next above. Sutures deep. Mouth oblong, slightly channelled below, inner lip spread on the body-whorl. Columella thickened, arched. Umbilicus closed. Base convex.

There are thirty specimens of this species in the collection of Mr. J. Smith, and they show a considerable variation in the width of the spiral angle, so that if we had the two extremes without the intermediate forms we might be led to consider them as distinct species.

[1] 'Descr. of some New Sp. of Carb. Gasteropoda,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 624, pl. xx. figs. 9–13.

M. compacta,[1] Don., is the species which this most resembles, but *M. compacta* has more convex whorls, less deep sutures, the additional keels on the body-whorl are absent, the apex is more obtuse, and the nucleus is much more flatly coiled. None of the individuals that I have seen show an open umbilicus, and it is open in some of the young specimens of *M. compacta*. Length of specimen (Pl. IX. fig. 6) $=5\frac{1}{2}$ millim.; width $=3$ millim. Length of specimen (Pl. IX. fig. 7) $=4\frac{1}{2}$ millim.; width about 2 millim. Length of specimen (Pl. IX. fig. 11)$=4\frac{1}{2}$ millim.; width about $1\frac{1}{2}$ millim.

Locality. Law, Dalry. Mr. Young also possesses examples from this locality, as well as from Crawfield, Beith.

Formation. Lower Limestone Series (d^3).

Section GLYPHODETA.

MURCHISONIA (GLYPHODETA) FIMBRICARINATA, Young & Armstrong. (Pl. IX. fig. 9.)

Murchisonia fimbricarinata, J. Young & J. Armstrong, 1874, Trans. Geol. Soc. Glasgow, vol. iv. p. 279; J. Armstrong, J. Young, & D. Robertson, 1876, Cat. West. Scot. Geol. Foss. p. 56; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 325; R. Etheridge, 1888, 'Foss. of Brit. Islands,' vol. i. Palæozoic, p. 301.

Shell small, conical, composed of more than seven whorls. Whorls rounded, very slightly angular about the middle. Sinual band situated on the widest part, broad and flattish, with a fine linear groove on each side. Ornamentation above the sinual band consisting of two or three fine lines; below, of two somewhat rounded bands, with an additional band on the body-whorl. Both the lines and bands are separated by grooves, those between the bands being the deepest. Lines of growth distinct, causing the spiral lines and bands to be almost beaded where they cross; on the sinual band they form strong raised crescents. Sutures deep, rather oblique. Mouth unknown.

The only species which this resembles is *M. zonata*,[2] Don., from which it may be distinguished by its greater spiral angle, less convex whorls, more prominent sinual band ornamented with raised crescents, and by its beaded lines and bands.

The single known specimen of this species is in the collection of Dr. John Young, Glasgow.

Length $=7$ millim.; width of body-whorl $=3\frac{1}{4}$ millim.

Locality. Robroyston.

Formation. Upper Limestone Series (d^3).

MURCHISONIA (GLYPHODETA) TÆNIATA, Phill. (Pl. X. fig. 5.)

Turritella tæniata, J. Phillips, 1836, 'Geol. Yorks.' pt. ii. p. 229, pl. xvi. fig. 7; T. Brown, 1849, 'Illustr. Foss. Conchol. Great Britain & Ireland,' p. 71, pl. xxxviii. fig. 7.

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[1] 'Descr. of some New Sp. of Carb. Gasteropoda,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 624, pl. xx. figs. 9–13.

[2] 'Notes upon some Carb. Sp. of *Murchisonia* in our Public Museums,' Quart. Journ. Geol. Soc. vol. xliii. (1887) p. 628, figs. 1–2.

Murchisonia tæniata, A. d'Archiac & E. de Verneuil, 1841, Bull. Soc. géol. France, ser. 1, vol. xii. p. 160; *iid.* 1842, Trans. Geol. Soc. ser. 2, vol. vi. pt. ii. p. 358; H. G. Bronn, 1848, Index Palæont. p. 748; L. G. de Koninck, 1851, 'Descr. Anim. foss. du Terr. Carb. de la Belgique,' Suppl. p. 698, pl. lviii. fig. 12; J. Morris, 1854, Cat. Brit. Foss. p. 259; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 327; R. Etheridge, 1888, 'Foss. of Brit. Islands,' vol. i. Palæozoic, p. 302.

Shell conical, elongated, composed of more than four whorls. Whorls convex, flattened rather below the middle by a broad level band. This band is slightly depressed below the surface of the shell, and is bounded on each side by two grooves. Lines of growth curve backwards to the band above, and are obscure both on the band itself and below. Sutures deep. Mouth unknown.

There is but one specimen of this shell in the Gilbertson Collection in the British Museum (Natural History), and I have not met with any others that can be clearly identified with it. The surface is so badly preserved that it is impossible to say whether there was really a sinus in the outer lip, and whether consequently the flat band on the whorls represents its position and is formed by the gradual and successive filling up of the sinus. We cannot, therefore, decide whether this species should be referred to the genus *Murchisonia* or whether it is more nearly allied with the American forms, *Turritella* (?) *Stevensana*, Meek & Worthen,[1] and *Turbonilla Swallowiana*, Gein.,[2] where there is no sinus, but the lines of growth are merely strongly curved. These American shells have since been referred by De Koninck to the genus *Aclisina*.[3] Of the other species of this genus *A. striatula*, De Kon., has the most strongly curved lines of growth. The species under discussion differs, however, from these in showing no traces of the numerous spiral threads with which their surface is ornamented; the whorls also are not so convex, and they are decidedly flattened about the middle by a broad band. I therefore place this shell in the genus *Murchisonia* provisionally.

D'Archiac and De Verneuil[4] mention a Devonian shell which they 'have some doubt in referring to this species' as it is too much worn for positive identification, and they do not figure it.

Length of specimen, of which only four whorls are preserved, = 24 millim.; width = 20 millim.

Locality. Not known.

Formation. Carboniferous Limestone (d^2).

Section Cerithioides, Haughton.

Murchisonia (Cerithioides ?) Oweni, sp. nov. (Pl. X. fig. 1.)

Shell conical, composed of more than five whorls. Whorls strongly angular below the middle, slightly angular above, just below the suture, flattened both above and below the strong angle. On the

[1] Geol. Surv. Illinois, 'Palæontology,' vol. ii. (1866) p. 382, pl. xxvii. figs. 8, 8 *a*.

[2] 'Carbonformation und Dyas in Nebraska,' 1866, p. 5, pl. i. fig. 19.

[3] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique, vol. vi. (1881) pt. iii. p. 86.

[4] Trans. Geol. Soc. ser. 2, vol. vi. (1842) pt. ii. p. 358.

upper part of the whorl, about midway between the angle and the suture, there is a flat band, level with the surface, bounded on each side by a groove. This band probably represents a sinus in the outer lip. The lines of growth are strong and distinct; they curve backwards to the band above and forwards below, but are not discernible on the band itself. Surface smooth. Sutures deep. Base flattened. Mouth imperfectly preserved, subrhomboidal, slightly longer than wide.

This shell bears some similarity to species of *Flemingia*, De Kon., but may be distinguished by its band, and the form of the outer lip as indicated by the lines of growth. It greatly resembles *Cerithioides telescopium*[1] in general form, in the structure of the band, and in the angularity, flatness, and smoothness of the whorls. It differs in its much smaller size, in the base being smooth instead of grooved, in the greater angularity of the whorls, and in the angle showing above the sutures. I place it provisionally in the section *Cerithioides*.

There are two specimens in Owens College Museum, Manchester. That figured (Pl. X. fig. 1) is the largest; it is crushed and only three and a half whorls are preserved, whose length is 9 millim., width $5\frac{1}{2}$ millim. The Museum of Practical Geology also contains three individuals all more or less imperfect, four and a half whorls being the most preserved.

Locality. Todmorden, on the border of Lancashire and Yorkshire.

Formation. Yoredales (d^3).

Section Caliendrum, Brown.

Murchisonia (Caliendrum) vittata, Phill. (Pl. X. figs. 6, 7.)

Buccinum vittatum, J. Phillips, 1836, 'Geol. Yorks.' pt. ii. p. 230, pl. xvi. fig. 14.

Caliendrum vittatum, T. Brown, 1849, 'Illustr. Foss. Conchol. Great Britain & Ireland,' p. 52, pl. xxxii. fig. 20.

Murchisonia vittata, A. d'Orbigny, 1850, 'Prodr. de Paléont. stratigr.' vol. i. p. 122; J. Morris, 1854, Cat. Brit. Foss. p. 259; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 327; R. Etheridge, 1888, 'Foss. of Brit. Islands,' vol. i. Palæozoic, p. 302.

Shell large, buccinoid, composed of more than six whorls. Spire varying in elevation. Whorls convex, ventricose, smooth, increasing somewhat rapidly, the body-whorl large compared with the length of the spire. Sinual band broad, flat, but slightly raised above the surface, bounded by a groove on each side, situated about the middle of the whorls of the spire. Lines of growth strong, curving backwards to the band above, forwards below, and arched on the band itself. Sinus in the outer lip deep. Mouth elliptical, longer than wide. Columella slightly arched forward. Sutures deep. No umbilicus. Test thin.

Captain Brown states that the lip is greatly reflected on the columella. The type is the only specimen that I have seen which exhibits this part of the shell, and it has an irregular thickened

[1] 'Notes on some New and Little-known Species of Carboniferous *Murchisonia*,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 573, pl. xvii. figs. 1, 4, 5, 8.

layer spread on the body-whorl; but it is difficult to decide whether this is really a reflection of the lip, or merely an incrustation resulting from the manner in which the shell is fossilized. He also says that the outer lip is reflected and that there is no anterior canal. None of the specimens that I have examined are sufficiently well preserved to give evidence of these points. I know of no Carboniferous species with which this can be confounded. It most resembles *Pithodea amplissima*, De Kon.,[1] in form, but has not the spiral lines and grooves which ornament that species.

The type (Pl. X. fig. 6) is in the Gilbertson Collection in the British Museum (Natural History). It possesses only four whorls, as the apex is broken. Its length is 64 millim.; height of body-whorl 47 millim.; width of body-whorl =44 millim.

Besides this specimen there are four others in the same collection, one (Pl. X. fig. 7) of which has the sinus in the outer lip well preserved. The apex is broken, and the four whorls which remain have a length of 45 millim.; width of body-whorl =35 millim.

Locality. Bolland.

There are also two specimens from Kildare in the British Museum, and two from the same locality in the Museum of Practical Geology, London. These latter consist of six whorls each, and have the apex broken; the surface is badly preserved. The Museum of Practical Geology also contains a specimen from Cloonlara, Co. Clare.

Captain Brown gives Queen's County as another locality.

Formation. Carboniferous Limestone (d^2).

Genus Worthenia, De Kon.

Worthenia tabulata, Conrad. (Pl. X. figs. 2, 4.)

Turbo tabulatus, T. A. Conrad, 1835, Trans. Geol. Soc. Pennsylv. vol. i. p. 267, pl. xii. fig. 1.

Pleurotomaria tabulata, T. A. Conrad, 1842, Journ. Acad. Nat. Sci. Phil. vol. viii. p. 272; J. Hall & J. D. Whitney, 1858, Rep. Geol. Surv. State of Iowa, vol. i. pt. ii. p. 721, pl. xxix. fig. 12; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 330; S. A. Miller, 1882, 'Amer. Pal. Foss.' p. 161.

Murchisonia angulata, J. E. Portlock, 1843, 'Rep. on Geol. of Londonderry,' p. 418, pl. xxxi. fig. 5 (non *M. angulata*, Phill.).

Worthenia tabulata, L. G. de Koninck, 1883, Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. viii. pt. iv. p. 65, pl. xxix. figs. 3, 4, & pl. xxxii. bis, fig. 5.

Shell conical, turreted, composed of more than six whorls. Whorls angular, increasing rather rapidly, slightly concave both above and below the angle. Sinual band situated on the angle rather below the middle of the whorls of the spire, formed either by a strong, sharp central keel with a shallow groove on each side, or else the keel may be more developed and convex and the grooves absent. There is a strong keel on the body-whorl below the sinual band, which is just hidden by the suture on the upper whorls. Surface covered by very fine spiral lines, which are less strong than

[1] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. vi. (1881) pt. iii. p. 88, pl. viii. figs. 1–3.

the lines of growth, with the exception of one or two upper ones on the higher whorls which are stronger and rendered moniliform by the lines of growth; this feature becomes fainter as the whorls increase. Lines of growth distinct and sharp, curving backwards to the band above and forwards below; on the band itself they are so strong as to form imbricated lamellæ, and the keel on the body-whorl is crenulated where they cross. Base more or less flattened. Mouth polygonal. Columella simple. No umbilicus. Test moderately thin.

In the Museum of Practical Geology, London, there are seven specimens marked *Pleurotomaria tabulata* which agree with that species as figured and described by Conrad, except that the spiral lines on the base are not rendered moniliform by the crossing of the lines of growth. On some of these individuals the sinual band is the same as on the type, being a strong convex keel; on others there is a shallow groove on each side of a sharp and less strongly developed keel. *Murchisonia angulata*, Portl., appears to be identical with Conrad's species. It has the sinual band formed in the latter way; the central keel is perhaps rather sharper, and the lateral grooves more marked, than on any of the other specimens; also the spiral angle is slightly less. But the different individuals vary somewhat, therefore it does not seem necessary to recognize it as a distinct variety. The surface of the higher whorls is not well preserved, but a small portion of the penultimate whorl shows traces of the crenulations on the upper part. The *Murchisonia angulata* of Portlock is quite distinct from either of the shells so named by Phillips in the 'Geology of Yorkshire,' this having a greater spiral angle and the ornamentation and form of the band being different. De Koninck identifies it with *Worthenia Waageni*,[1] from which it differs in the band being nearer the middle of the whorl, in the space between it and the lower keel being wider, and in not possessing an umbilical chink.

Portlock's type (Pl. X. figs. 2, 2 *a*), which is in the Museum of Practical Geology, has the apex broken and only four whorls remain; these have a length of 30 millim., and a width of about 20 millim.

Locality. Aghalurcher, Tyrone.

Formation. Carboniferous Limestone Shale (d^3). Probably the middle division (Calp).

The specimen figured (Pl. X. figs. 4, 4 *a*, *b*) is 33 millim. in length and 28 millim. in width.

Locality. Hammerton Hall, Slaidburn (near Clitheroe), Lancs.

Formation. Bottom of Yoredale Shales (d^3).

In the Woodwardian Museum, Cambridge, there is a single specimen of this species mounted on the same tablet as *M. kendalensis*, M'Coy.

Locality. Kendal.

Formation. Mountain Limestone (d^2).

[1] Ann. Mus. Roy. Hist. Nat. Belgique, 'Faune du Calc. Carb. de la Belgique,' vol. viii. (1883) pt. iv. p. 67, pl. xviii. figs. 32, 34, & pl. xxxii. bis, figs. 32–35.

EXPLANATION OF PLATES VIII.–X.

Plate VIII.

Figs. 1, 2. *Murchisonia cincta*, sp. nov. Fig. 1, front view. × 9. Glencart, Dalry. Collection of Dr. John Young. Fig. 2, back view. × 8. Fig. 2 *a*, apex, enlarged. Law, Dalry. Collection of Mr. John Smith.

Figs. 3–8. *M. dispar*, M'Coy. Fig. 3, back view, nat. size. Fig. 8, another specimen, nat. size, both obliquely deformed. Cork. Collection of Mr. J. Wright. Fig. 4, back view, nat. size. Fig. 4 *a*, portion of another specimen, enlarged to show form of band. Fig. 6, mouth of small specimen, nat. size. Avon Section. Bristol Museum. Fig. 5, type, × 3. Fig. 5 *a*, portion of whorl, enlarged to show contour. Lowick. Woodwardian Museum. Fig. 7, wax impression, × 2. Osgathorpe. Oxford Museum.

Figs. 9, 11, 12. *M. fusiformis*, Phill. Fig. 9, type, × 3. Bolland. Gilbertson Collection, British Museum (Natural History). Fig. 11, front view, × 2. Settle. York Museum. Fig. 12, back view, × 2. Settle. Woodwardian Museum.

Figs. 10, 13. *M. Youngiana*, sp. nov. Fig. 10, front view, × 6. Collection of Dr. J. Young. Law, Dalry. Fig. 13, × 5. Fig. 13 *a*, apex, greatly enlarged. Collection of Mr. Smith.

Plate IX.

Fig. 1. *M. Thomsoni*, sp. nov., × 5. Craigenglen. Collection of Mr. Thomson.

Fig. 2. *M. Marri*, sp. nov., × 2, wax impression. Shap. Woodwardian Museum.

Fig. 3. *M. dalryensis*, sp. nov., × 6. Dalry. Collection of Mr. Thomson.

Fig. 4. *M.* (*Hypergonia*) *fastigiata*, sp. nov., front view, × 3. Clattering Ford, Cumberland. Museum of Practical Geology.

Fig. 5. *M.* (*H.*) *M'Coyi*, sp. nov., × 6. Fig. 5 *a*, body-whorl of another specimen, × 8. Wax impressions. Widdle Fell. My own collection.

Figs. 6, 7, 11. *M.* (*Stegocœlia*) *variabilis*, sp. nov. Fig. 6, back view of specimen with wide spiral angle, × 6. Fig. 6 *a*, apex, greatly enlarged. Fig. 7, front view of specimen with medium angle, × 8. Fig. 7 *a*, apex, greatly enlarged. Fig. 11, front view of specimen with smaller angle, × 8. Law, Dalry. Collection of Mr. Smith.

Figs. 8, 10. *M.* (*Hypergonia*) *deplanata*, sp. nov. Fig. 8, front view, × 8. Collection of Dr. J. Young. Fig. 10, apical whorls, × 7. Museum of Science and Art, Edinburgh. Glencart, Dalry.

Fig. 9. *M.* (*Glyphodeta*) *fimbricarinata*, Young & Armstrong, back view, × 5. Fig. 9 *a*, portion of whorl, enlarged. Robroyston. Collection of Dr. J. Young.

Plate X.

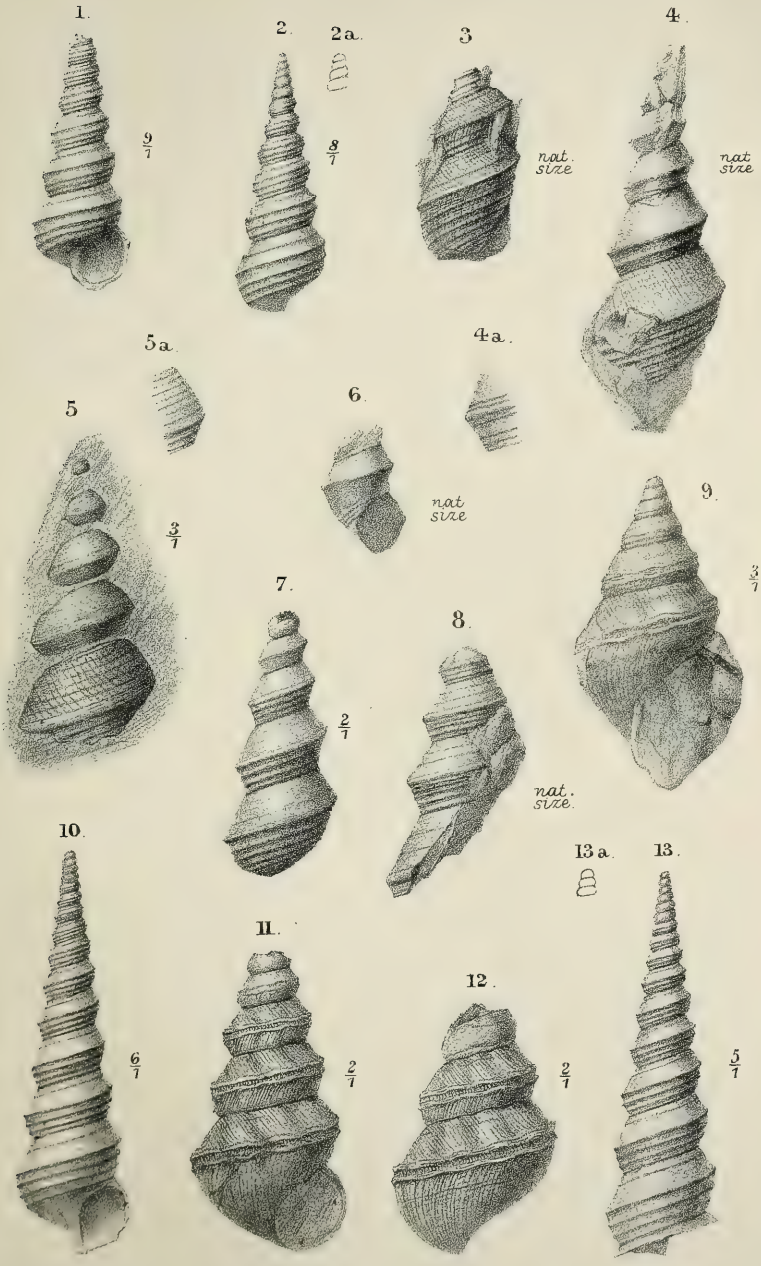
Fig. 1. *M.* (*Cerithioides?*) *Oweni*, sp. nov., × 4. Owens College Museum, Manchester. Fig. 1 *a*, portion of whorl of another specimen, × 6. Todmorden. Museum of Practical Geology.

Figs. 2, 4. *Worthenia tabulata*, Conrad. Fig. 2, type of Portlock's *M. angulata*, nat. size. Fig. 2 *a*, portion of band, enlarged. Aghalurcher. Fig. 4, back view of another specimen, nat. size. Fig. 4 *a*, portion of fourth whorl from base, × 4. Fig. 4 *b*, band of penultimate whorl, enlarged. Slaidburn. Museum of Practical Geology.

Fig. 3. *M.* (*Stegocœlia*) *Smithiana*, sp. nov., × 6. Law, Dalry. Collection of Mr. Smith.

Fig. 5. *M.?* (*Glyphodeta?*) *tæniata*, Phill, nat. size. Gilbertson Collection, British Museum (Natural History).

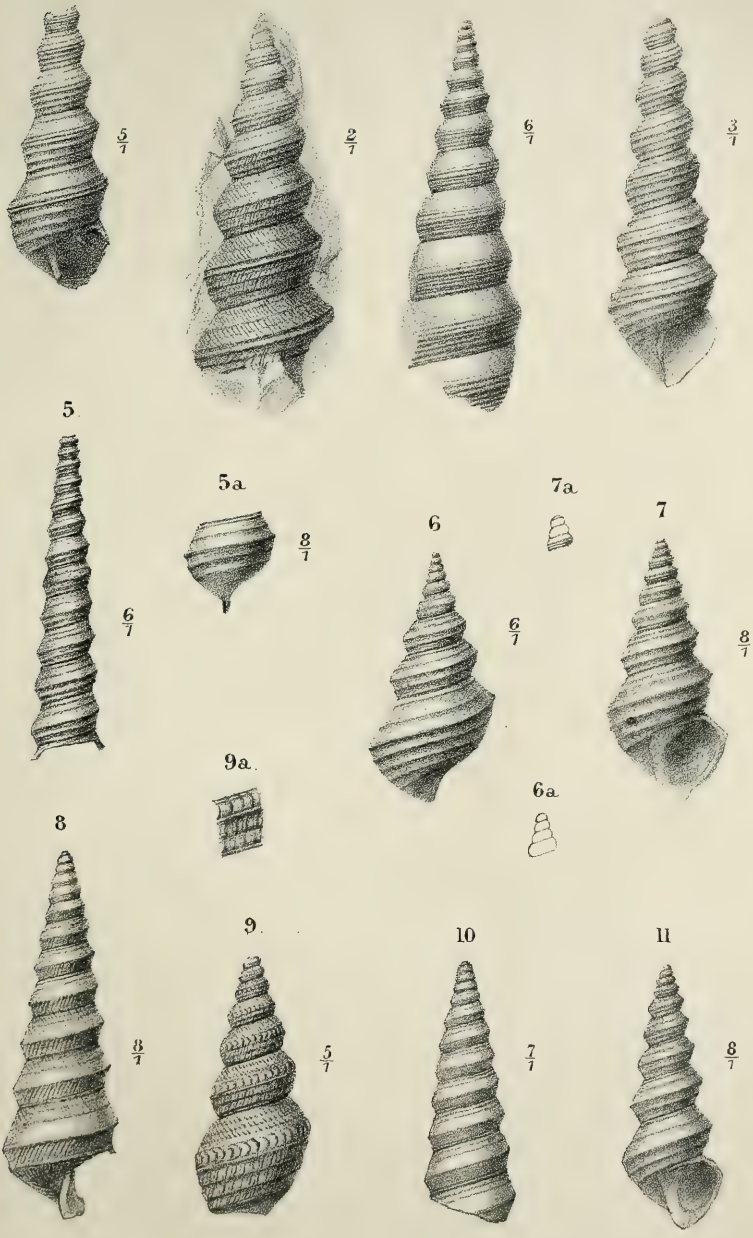
Figs. 6, 7. *M.* (*Caliendrum*) *vittata*, Phill. Fig. 6, front view of type, nat. size. Fig. 7, back view of another specimen, nat. size. Bolland. Gilbertson Collection, British Museum (Natural History).



J Donald del. F.H. Michael lith.

Mintern Bros. imp.

MURCHISONIA.



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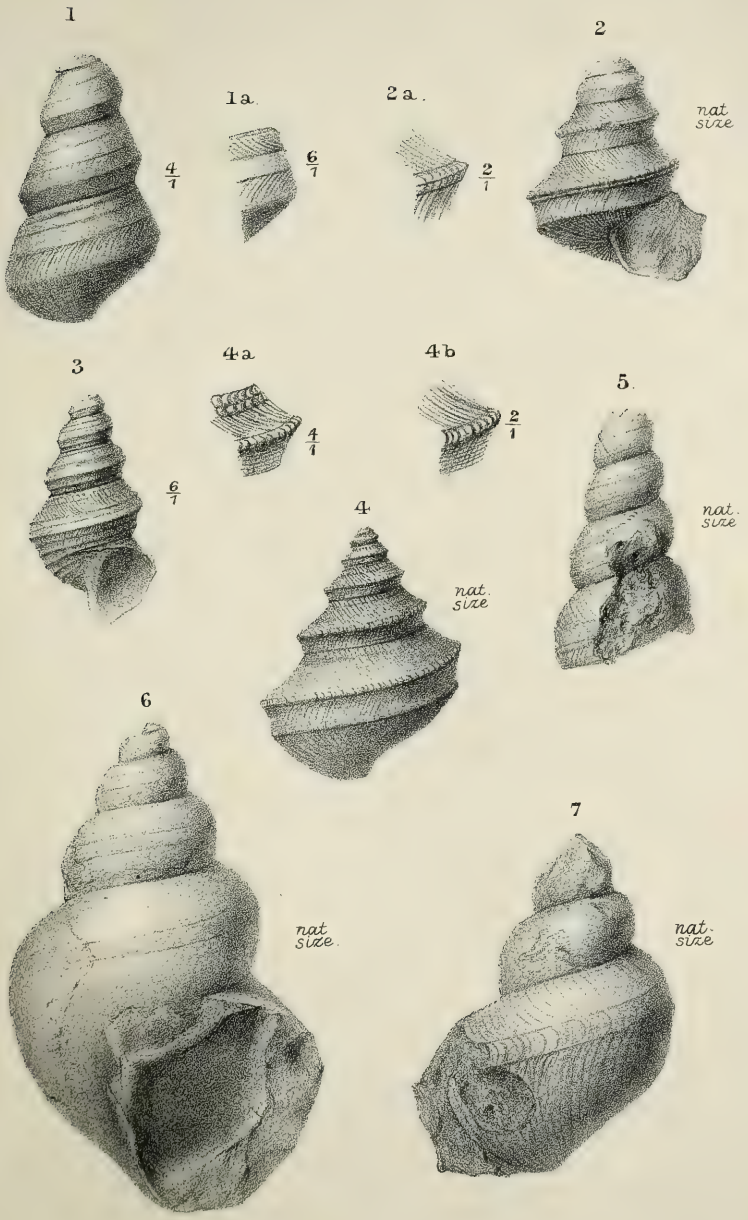

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MURCHISONIA AND WORTHENIA.

19. *The* Whitehaven Sandstone Series.

By J. D. Kendall, Esq., F.G.S. (Read February 20th, 1895.)

[Abstract.]

The Whitehaven Sandstone, with its associated shales, is a purple-grey deposit sometimes having a thickness of 500 or 600 feet. The Author gives details of a large number of sections of the series, which also contains thin coal-seams and occasionally *Spirorbis*-limestone.

He combats the view that it is stained Middle Coal Measure deposit, and gives his reasons for believing that it rests unconformably upon the Middle Coal Measures, and also that it has not received its colour by abstraction of colouring-matter from the Permian beds, but that the colour actually belongs to the deposit. He describes sections which lead him to suppose that the deposit has a wider distribution over the Cumbrian district than is allowed by previous writers.

Discussion.

Mr. T. V. Holmes believed that geologists had always acknowledged the unconformability of the Whitehaven Sandstone, *at Whitehaven*, to the beds on which it rested. The difficulty was to identify it in other places. In the Yorkshire Coalfield, where he had worked on the Geological Survey before going to Cumberland, the Red Rock of Rotherham was analogous in position to the Whitehaven Sandstone. But the Yorkshire Coalfield was almost entirely free from Glacial Drift, and the Coal Measure sandstones, excepting the Red Rock, were invariably buff or brown in colour. It was therefore possible to trace the Red Rock of Rotherham from place to place, and to note its relations to the ordinary conformable Coal Measure rocks. Yet the country occupied by the Coal Measures and Permian-Triassic rocks in Cumberland was not only almost wholly drift-covered, but the surface-features were drift-features, and the streams and sea-cliffs often showed nothing but drift for many miles continuously. In addition, rocks like the Whitehaven Sandstone, of purple-grey tint, could be seen on every Carboniferous horizon from the Carboniferous Limestone upwards, and were visible on the rivers Esk, Liddel, and Line, on the Scottish Border, as well as in the streams of Western Cumberland. It was therefore obviously impossible to trace the Whitehaven Sandstone across the country, or to assume that a certain rock, miles away from Whitehaven, was the Whitehaven Sandstone on the mere evidence of its appearance. In 1883, Mr. Kendall read a paper on 'The Structure of the Cumberland Coalfield' at a meeting of the North of Engl. Inst. Min. Eng., which was published in the Proceedings of that Society (vol. xxxii.). In this paper the Whitehaven Sandstone, and its identification in certain localities, was fully discussed. He (the speaker) had pointed out in a short

paper in the Trans. Cumb. and Westm. Assoc. (No. ix., 1885), that the evidence of appearance alone was worthless, and that the plate of vertical sections illustrating Mr. Kendall's paper seemed to him adverse to that writer's views as regards Bull Gill and Aspatria. He would add, in conclusion, that the evidence of colliery-workings was the only means by which the identity of any given rock with the unconformable Whitehaven Sandstone could be established, and he did not gather from the paper which had been just read that any progress had been made in that direction since the publication of Mr. Kendall's paper of 1883.

Mr. Strahan had recently visited part of the area referred to with the Author, but had not been satisfied that there was any definite base to the Whitehaven Sandstone Series, or any unconformity between it and the productive measures below. The cliff-section referred to by the last speaker showed lenticular bands of conglomerate, near or at the base of the purplish sandstone, accompanied by signs of slight erosion; but such appearances were common in all Coal Measures, and could scarcely be described as unconformities. The colour was in his opinion due to staining. The purple hue was characteristic of such conditions and was not confined to Coal Measures, but was as conspicuous in Millstone Grit or whatever other permeable rock was or had been overlain by the Red Rocks. The base of the series, according to the Author, was sometimes a conglomerate, sometimes arenaceous, sometimes argillaceous, nor could the horizon be traced by fossils. These admissions seemed to him to indicate that the Author had been influenced by the colour in determining the base of the series in different parts of the area, which the speaker believed to be an unsafe guide. Yet on the determination of a base, and its relative position to the workable coal-seams, depended the theory of an unconformity.

While differing from the Author on these theoretical conclusions, he had pleasure in testifying to the ability with which he had mastered the details of a most complicated and interesting area.

Mr. Marr could confirm the existence of rocks of various ages around the Lake District area which had been stained red, subsequently to their formation. The Whitehaven Sandstone flora was well represented in the Woodwardian Museum; and he had no doubt that a careful examination of the plants obtained from the typical Whitehaven Sandstone would give a clue to its age.

20. *A new* Ossiferous Fissure *in* Creswell Crags. By W. L. H. Duckworth, Esq., and F. E. Swainson, Esq. (Communicated by Prof. T. McK. Hughes, M.A., F.R.S., F.G.S. Read March 6th, 1895.)

[Abstract.]

The fissure explored by the Authors is about 30 feet above the level of the artificial lake at Creswell Crags. At the top occurred a white earth (with human and other remains), passing down into a red sand with remains of fox, badger, roe-deer, and other mammals. Beneath the latter deposit, and separated from it by a fairly sharp line of demarcation, came the cave-earth proper, with Palæolithic implements and bones of *Rhinoceros tichorhinus*, *Bison priscus*, *Ursus spelæus*, *Hyæna crocuta* var. *spelæa*, and *Cervus tarandus*.

The Authors suppose that this cave-earth is derived from an older deposit and has been transported to its present place by water, though there is evidence that the transport has been from no great distance. Consequently they followed the fissure inwards, until brought to a stop by a mass of travertine, which they penetrated with a small hole. They hope to explore the fissure beyond this travertine on a future occasion.

Discussion.

Mr. E. T. Newton remarked on the value of the work which the Authors were carrying out, and corroborated the determination of the bones exhibited. At the same time he suggested the desirability of carefully collecting the remains of the smaller vertebrates, both from the cave-earth and the overlying deposits: information as to the period to which some of the Pleistocene animals lingered in this country being much wanted.

Mr. Clement Reid suggested that in any search for the smaller fossils especial attention should be paid to any associated plant-remains, for plants ought to throw much light on the climatic conditions, left uncertain by the mammalia.

The President and Mr. C. W. Andrews also spoke.

Mr. W. L. H. Duckworth, in reply, said that he must admit not having made a detailed study of the remains other than human found in the more superficial layers in the floor of this fissure. The bones were for the most part those of birds. Nor could he give any record of the occurrence of seeds, etc., of plants in the cave-earth proper. With regard to the tooth of a fox smaller than *Canis vulpes*, it was found in what the Authors had called the 'middle layer' (composed of red sand), and so belongs rather to the more superficial strata than to the cave-earth proper. In conclusion, he took this opportunity of thanking those Fellows who had spoken, for their kind suggestions of lines of investigation.

21. *On the* Loess *and other* Superficial Deposits *of* Shantung (North China). By S. B. J. Skertchly, Esq., and T. W. Kingsmill, Esq. (Communicated by Sir John Evans, K.C.B., F.R.S., F.G.S. Read February 6th, 1895.)

[Abridged.]

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This paper is based upon a recent journey by the authors, extending right across Shantung, from Chefu in the east into Chihli in the west; one of us, however (T. W. K.), had previously traversed the country southwards, and had studied the loess in the provinces of Kiangsu, Shanse, Anhwei, Honan, Shantung, and Chihli. During the recent journey, lasting from April till the end of July, 1892, we had unusual opportunities of studying the surface-beds, and as the conclusions we arrived at were threshed out from time to time, and position after position had to be abandoned, it has been thought best to throw our observations into a more or less narrative form.

I. Superficial Deposits of North China.

We are of opinion that much of the objection taken to the marine theory of the loess is due to a disinclination to concede such great changes in the configuration of Asia, within comparatively recent times, as are therein involved, and we therefore proceed to show that China has been to a large extent submerged even since the loess period. Hitherto little attention has been paid by geologists to the interesting beds which seem to prove this submergence. The series as at present made out is, in descending order,—

1. Modern Fluviatile Deposits.
2. Marine Sands.
3. Old River-gravels.
4. Loess.
5. Basement-gravels.

1. *Modern Fluviatile Deposits.* These consist of the huge delta-deposits of the Yangtse, the far less conspicuous silts and sands of the Yellow River, and the gravels and sands of the present streams. As they apparently belong to the present state of things, and do not affect the loess question, they are merely recorded here as the newest of the series, and now in process of formation.

2. *Marine Sands.* In the spring and summer of 1887 one of the authors (T. W. K.) had occasion to conduct some surveys for the Imperial Chinese Government in the province of Shantung, and he there found a formation of later origin than the loess and undoubtedly marine. Largely indeed the newer deposits, which range possibly into the human epoch, were the result of the denudation of the loess; and, as they seem to throw considerable light on the early condition of that deposit, they are worth noting.

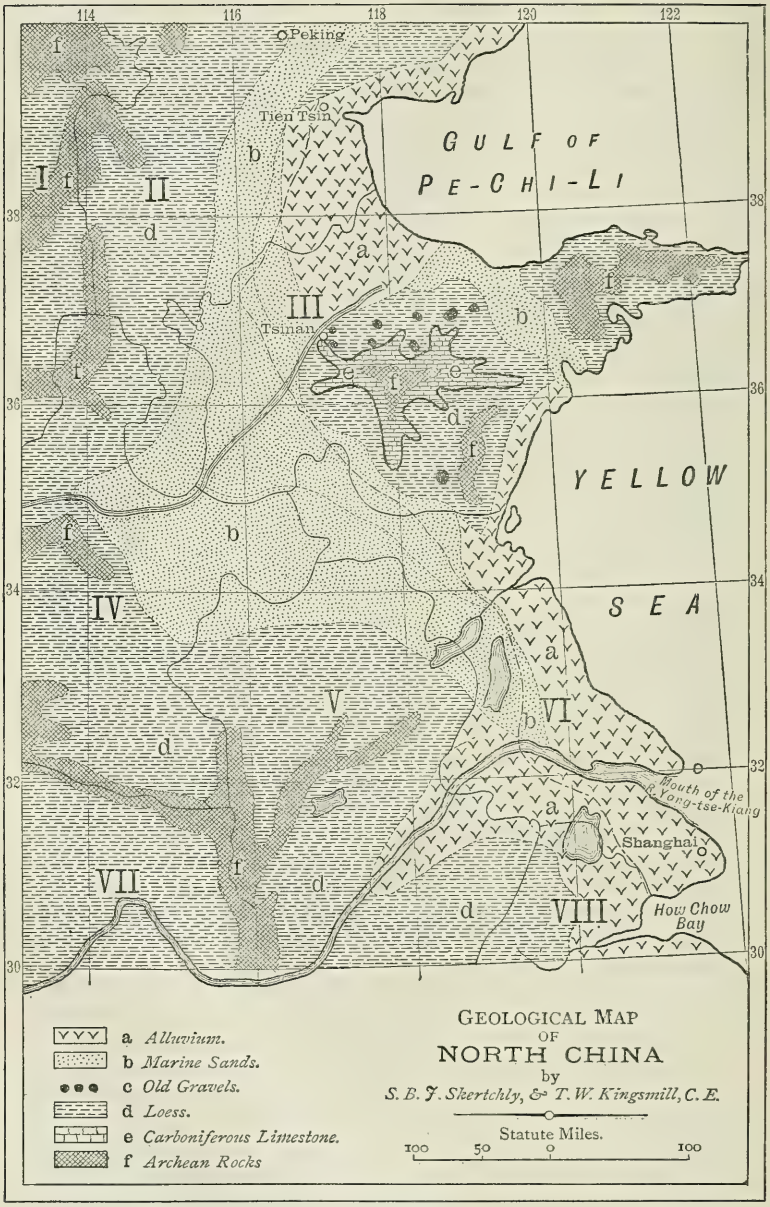
The author's route lay from Shanghai to Chin-kiang, on the lower plain of the Yangtse, and thence by the so-called Imperial or Grand Canal (the Yün-liang-ho, or 'Grain-bearing River' of the Chinese) to Ts'ing Kiang-pu on the old bed (1250–1854) of the Yellow River near Hwai-an-fu. From Ts'ing Kiang-pu the writer went overland, following nearly the line of the canal to the neighbourhood of Süchow [1] (lat. N. 34° 25′, long. E. 118°), and then struck off through the centre of Shantung by I-chow and Tai-an-fu to Tsi-nan-fu, the provincial capital, whence he again struck the northern portion of the canal, and carried a survey and levellings from Lin-t'sing-chow on the borders of Pe-chi-li (lat. N. 37° 10′, long. E. 116° 2′) down to Tsin-ing-chow, near the southern limit of the province (lat. N. 39°), returning to Teh-chow (lat. N. 37° 35′, long. E. 116° 30′), and thence descending the Wei-ho to Tientsin.

The levels proved, what had been before suspected, that the entire west of Shantung, so far from being, as frequently represented, a gently sloping alluvial deposit, was really the bed of an old marine strait dividing the highlands of Shantung from those of Honan and Shanse, and the writer was able to trace them from the valley of the Yangtse at Sien-mü-miao (lat. N. 32°, long. E. 118°), 20 miles below Chinkiang, by Yang-chow-fu (lat. N. 32° 25′, long. E. 119° 20′) through Northern Kiangsu, Western Shantung and Pe-chi-li up to Tung-chow (lat. N. 39° 54′, long. E. 116° 41′) near Peking. The western limit bent westward in Honan to approximately long. E. 111°, and returned to the east along the foot of the highlands of Western Pe-chi-li. The mountain-ranges and highlands of Shantung east of 116° long. E. rose as at least two islands in the sea, while Lower Kiangsu and the western fringe of the Gulf of Pe-chi-li appeared as the alluvial deposits of the Yangtse and Yellow Rivers respectively.

When first struck, in an island of the Yangtse near Sien-mü-miao, the marine sands were seen in a bank of coarse yellow sand extremely false-bedded—a true beach-deposit, though a cursory examination did not then disclose any fossils. In the neighbourhood of Yang-chow-fu and at Sien-mü-miao similar banks occurred, rising some 14 to 20 feet above the present level of the river, and at intervals up to Ts'ing Kiang-pu (lat. N. 33′ 40°, long. E. 119° 40′) similar beds occurred. At Ts'ing Kiang-pu the old bed of the Yellow River was met with, not, as might be expected, lying in a valley of denudation, but actually raised several feet above the level of the plain: the river had been restrained from overflowing the latter by embankments, now ruined, some 30 feet high.

[1] All positions are approximative.

Fig. 1.



Note.—In the above map the Yellow River is erroneously made to end in the alluvial flat north-east of Tsinan: it should have been continued to the Gulf of Pe-chi-li. For 'How Chow Bay' read 'Hang Chow Bay.'

EXPLANATION OF THE MAP OF PART OF NORTH CHINA (fig. 1).

This map has been drawn to illustrate the lie of the superficial deposits, hence no attempt has been made to divide the Palæozoic rocks, save into Carboniferous Limestone and Archæan, which form the mountain-masses; the igneous rocks are also omitted. Boundaries of provinces are shown and numbered as under:—

I. Shanse.
II. Chihli.
III. Shantung.
IV. Honan.
V. Anhwei.
VI. Kiangsu.
VII. Hupeh.
VIII. Chehkiang.

In order not to complicate the map, very few names are inserted in it, but the approximative positions of all the important localities, rivers, lakes, etc., referred to in the paper are given in brackets when first mentioned. The system of transliteration used in the paper is that of Giles.

Most maps of China indicate the River Hwai as here flowing out by Hwai-an-fu from the Hung Tsze lake (lat. N. 33° 30′, long. E. 119°) to the sea, and indeed prior to the 13th century such was its course. When, however, the Yellow River took possession of this channel the Hwai, which had before the Christian era been connected by artificial channels with the Kao-ying lake (lat. N. 33°, long. E. 119° 10′), was entirely deflected into this latter course, and has since the 13th century discharged its waters by Sien-mü-miao into the delta of the lower Yangtse.

Remains of these old watercourses exist some few miles north of Ts'ing Kiang-pu (lat. N. 33° 40′, long. E. 119° 40′). The general surface of the land is here some 70 feet above the sea-level, and the old streams have cut valleys, showing sections of the beds, some 40 to 45 feet deep. They consist of fine sands and gravels, and in the few hours available the writer found the ordinary marine shells *Cardium*, *Ostrea*, *Bulla*, etc. Without a break these beds extend the whole way to the north of Pe-chi-li, their summit-level being near Kai-fung-fu, in Honan, whence they spread out like a fan, reaching to near Tientsin in the north, and below Yang-chow in the south, the fall of the surface averaging 1·38 foot per mile, or 0·260 per 1000. The highest level in the strait through which the Yün-liang-ho has been carried is the Shu-shan-hu (lat. N. 35° 15′, long. E. 117°), an artificial lake intended as a reservoir to supply the canal north and south, the surface of which is about 135 feet above sea-level. This disposition will explain the unstable nature of the lower course of the Hwang-ho, which has at times oscillated between Tientsin, where it was found at the earliest dawn of Chinese history, and Sien-mü-miao, where for more than a year (1887–88) it found an exit and mingled its waters with those of the mightier Yangtse.

These marine sands, which for convenience may be provisionally called the 'Yang-chow[1] Marine Sands,' though younger than the loess (upon which in fact they often lie), are older than the alluvial plain of the Yangtse, under which they disappear. The junction of

[1] From the ancient division of Yang-chow, one of the twelve provinces of the Great Yü.

the alluvial plain and the loess is very well marked in places, more especially in the neighbourhood of Chinkiang, on the Yangtse. On the right (southern) bank of the river the loess, much denuded and partially re-arranged, stretches down some 22 miles to hills of ancient sandstone (probably Silurian), the Chushan, which have protected it from further denudation, and here it ends in a line of rounded cliffs, the old sea-coast before the commencement of the alluvial plain. The distinction between the two is here very marked, the undulating plain of the loess contrasting with the uniform level of the delta. These cliffs, forming headlands and bays, can be distinctly traced from the summit of the hills, trending southward for some miles. On the one side is seen the undulating loess, with its valleys of denudation; on the other the delta, intersected by creeks only a few feet below the surface, and without appreciable current, showing that since the commencement of the delta no change of any moment has taken place in the sea-level.

These Yang-chow Marine Sands were again met with in force by both authors in their recent journey through Northern Shantung. They were first observed between Chefu (lat. N. 37° 33′, long. E. 121° 23′) and Lai-chow-fu (lat. N. 37° 12′, long. E. 119° 53′) as outliers upon the loess, and then to the west of that city they stretched for miles together, often false-bedded, sometimes rising in ridge-like banks about 80 feet high and trending N.N.W. This was very marked between Sin Ho (lat N. 36° 51′, long. E. 119° 34′) and Han Ting (lat. N. 36° 46′, long. E. 119° 15′) about 60 miles west of Lai-chow-fu. The sands here afford fine, clean, sparkling drinking-water, a great comfort in these plains. Their distribution is shown on the map (fig. 1, p. 240). The greatest elevation that they reach is about 200 feet in the district mentioned.

As the Yangtse flows into the Yellow Sea—an almost land-locked expanse, nowhere till the coast of Japan is approached exceeding 50 fathoms in depth, and with no marked currents except locally about the Chusan Archipelago—the growth of the delta is fairly constant, averaging perhaps as much as 2 square miles *per annum*. This might afford a fair estimate of the actual age of the river, but calculations are rendered difficult, firstly, by want of any survey of the districts north of the river, and secondly, by the fact that the earlier work of the river must have consisted mainly in filling up the former extensive seas now represented by the lakes and lowlands of Honan and Hupeh and the basin of the Poyang in Kiangsi, besides large tracts of low-lying land in Anhwei. At the earliest period of which any traces remain, the waters of the Yangtse seem to have mingled with those of the Ts'ient'ang (lat. N. 30°, long. E. 120°), while to seaward a raised bank extended northerly from Yu Yao (lat. N. 30° 4′, long. E. 121° 8′) in Chehkiang as far, at least, as Taitsan (lat. N. 31° 30′, long. E. 121°) north of Shanghai; and behind this extended a lagoon or lagoons, of which the Taihu in lower Kiangsu is the present representative. The seaward face of this bank is marked by a shell-bed (containing *Ostrea*, *Cardium*, *Trochus*, and other estuarine shells) whose con-

dition, spread out in large indurated masses, shows that at that time the coast of the Yellow Sea was washed by comparatively clear water, in marked contrast with its present mud-laden condition.

Prior to this, during the deposition of the Yang-chow Marine Sands, the waters of the Yellow Sea must have stood at a level about 200 feet higher than is now the case, and have covered the lowlands of Shantung, much of Northern Kiangsu, a considerable extent of Honan, and the entire eastern portion of Chihli. In places north of the Yangtse, as near Ting-yuan-hyien (lat. N. 32° 32′, long. E. 117° 30′) in Anhwei, near Fung-yang-fu (lat. N. 32° 40′, long. E. 117° 20′), the boundary of the loess eastward is as well marked by ranges of old bluffs as the subsequent coast-line at Chushan during the earlier part of the Yangtse delta-forming period.

Doubtful deposits of this age, with marine shells, occur in Hong-kong Island, and at Amoy, Swatow, and near Takow in Formosa. These we have seen, but not since we worked out the present scheme.

3. *Old River-gravels.* The old river-gravels of Shantung form a very interesting set of deposits. They were first seen by one of the writers (T. W. K.) in 1887, near I-chow-fu (lat. N. 35° 5′, long. E. 118° 30′) in Southern Shantung. Here, as elsewhere in the province, they constitute a conglomerate of limestone-pebbles in a calcareous cement, the component fragments varying from fine gravel-stones to heavy shingle. More than 90 per cent. of the pebbles are Carboniferous Limestone, and indeed when the gravels were first seen they were looked upon as a conglomerate of Carboniferous age. Their true character soon made itself known, when they were traced to their origin in the heads of valleys in the Carboniferous Limestone-ranges of Tsi-nan-fu.

The conglomerate is exceedingly hard, and hence has resisted the denudation that swept away the looser material which doubtless originally accompanied it. The beds often stand out as bosses and banks upon the loess-plain, just as, and for similar reasons, many of the ancient gravels of Cambridgeshire and Norfolk rise above the Chalk. So eminently calcareous are they, that in places where no limestone is locally available, as at Chow Ts'un (lat. N. 36° 48′, long. E. 118° 3′), they are used for lime-burning. From their very nature they are fragmentary, ranging from 1 or 2 to over 6 feet in thickness, sometimes only a few feet in length, sometimes continuous for hundreds of yards, and from 8 to 30 yards in width. So compact is the mass that fragments 6 or 7 feet wide and 20 to 30 feet long are often seen projecting like shelves from the loess, and at one place we rode through a chasm 15 feet wide spanned by one of these masses hardly a foot thick. It is frequently used as a rough building-stone for retaining-walls.

In the great Carboniferous Limestone district which flanks the sacred T'ai Shan range (lat. N. 36°, long. E. 117°), these relics of prehistoric rivers are still to be seen clinging to the valley-sides.

They can be traced at intervals from the hills out on to the loess-plain, and not unfrequently five or six may be seen at different levels on a valley-side. About 80 per cent. of their courses are quite independent of the present drainage-system, and beds sometimes cross each other. Often, too, the roads, which from centuries of traffic have become worn below the surface of the soil, climb laboriously over one side of these old courses, and as abruptly descend on the other, especially in the metropolitan prefecture of Tsi-nan-fu (lat. N. 36°, long. E. 117°).

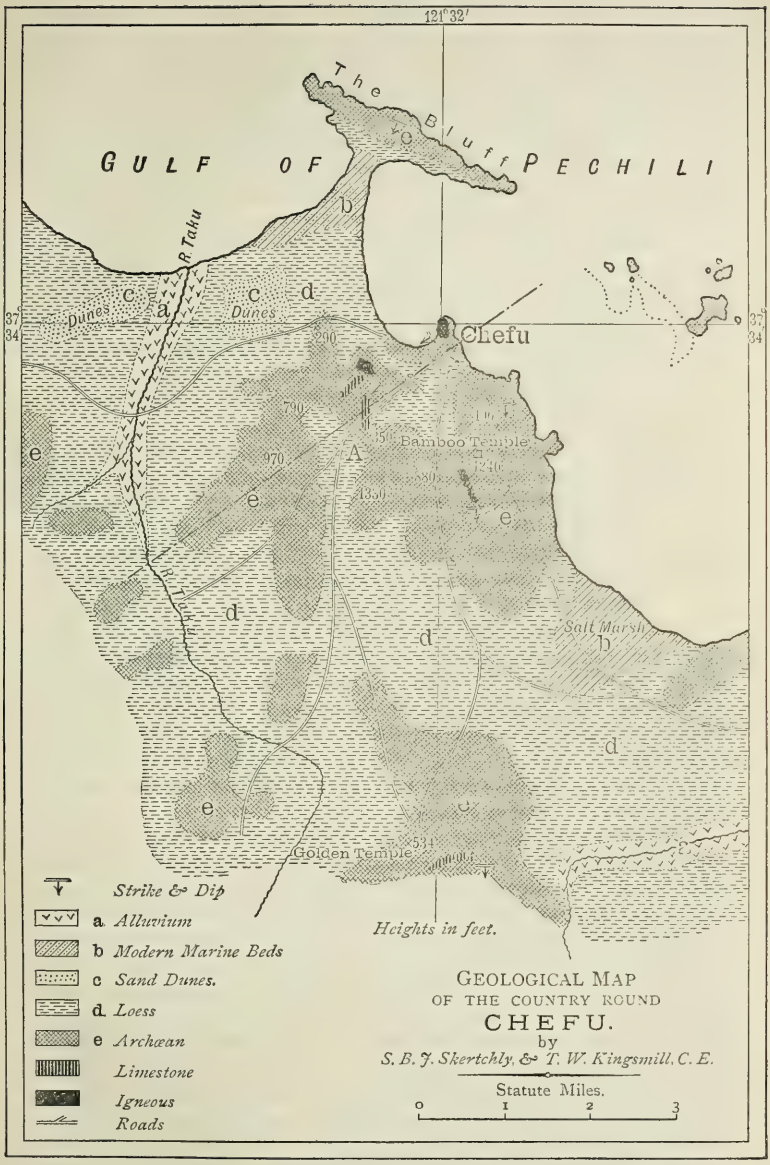
In many respects the old river-beds differ widely from those of streams now traversing the same district. The present courses are, where paved with gravel, worn down to the bed-rock, while the old beds frequently lie from 50 to 100 feet above it, the gravel often resting on a level bed of re-arranged loess. Then, too, in the recent river-beds, wherever the gravel is made of limestone-pebbles there is no tendency to cement into conglomerate. These recent streams are distinctly torrential, few running all the year through, and most being quite intermittent, rushing down the hillsides during the rainy season and ceasing immediately afterwards. As most of the present rainfall occurs in heavy downpours within a period of two months, the dry watercourses are one of the most prominent features in a Shantung landscape. Most of the drainage in the limestone districts takes place in almost land-locked valleys; and from these the waters escape by underground channels, finally emerging in springs slightly above the level of the general sandy plain. It is thus that the present Siao Ts'ing Ho (lat. N. 37° 15′, long. E. 118° 55′), or lesser Ts'ing, is fed by springs which rise at the city of Tsi-nan-fu (lat. N. 36° 40′, long. E. 117° 2′), built on the edge of the limestone region, where that rock disappears under the outermost fringe of the loess, which in its turn passes under the marine sands.

The age of these old gravels is readily determined. They are newer than the loess, but older than the Marine Sands, or more probably contemporaneous with them. This is proved by their overlying the loess, and never being found upon the area of the Marine Sands. As we never saw them pass below the sand, they probably belong to that period when Shantung formed two islands, round whose coasts the sands were deposited, and down whose slopes the perennial streams flowed.

The lie of these old gravels is well seen in a section laid bare in the banks of a little stream at Sze Chuang, south of Tsi Chuan, where the beds are exposed down to the Coal Measures.

4. *The Loess in the Chefu District* (fig. 2). The first travellers over the loess, struck with its terrace-like character, unhesitatingly referred its origin to a large freshwater lake or lakes; and the occurrence of land-shells and sub-fossil mammalian remains lent strength to the hypothesis. The possibility of such an origin again forced itself upon the authors when in April 1892 they found themselves at Chefu, *en route* for Tsi-nan, the capital of the province of Shantung, whither they were bound on geological work intent. The road for the entire distance (over 600 miles were traversed) lay upon

Fig. 2.



Note.—This map is based on a sketch-survey by R. W. Hurst, kindly lent to us by Mr. Carrall, F.G.S., Commissioner of Customs at Amoy. The geological lines were laid down by us in the field, and illustrate admirably the lie of the loess. Richthofen does not seem to have gone over this ground, as he shows no superficial deposits at all, save a slight alluvium fringing the streams. ('Atlas v. China—Ost Shantung,' pl. iv.)

or in close proximity to the superficial deposits, and the nature of the authors' expedition gave them ample opportunities for examining the beds; indeed, every exposure was noted, and a continuous section constructed, as well as a detailed map of the Chefu district, and a more general one of this and the neighbouring provinces.

One of us (T. W. K.) had unhesitatingly declared for the marine character of the loess; but, being anxious not to invalidate the results of the journey by any preconceived theories, it was agreed that the two should work out the deposits conjointly, and that no opinion, until accepted by both on independent testimony, should be placed on record. This condition became the easier because it was by no means clear that the superficial deposits in the neighbourhood of Chefu, on which our investigations began, in any way represented the loess. And, as a matter of fact, it was only by slow degrees, as we advanced westward and noted the gradual changes in colour and structure, that we recognized the representative character of the local formations.

The older rocks of this part of Shantung consist entirely of quartzites, schists, gneiss, and crystalline limestones, all belonging to the Archæan series, with intrusive granites and diorites. They form picturesque mountainous hills, rising to 1500 feet, which wind about and so form almost land-locked valleys, whose beds are from 200 to 300 feet above sea-level. The loess sweeps from the sea-level up into these valleys, and, looking down upon them and over the plain from the hills, the terrace-structure is so marked that one's memory harks back instinctively to the terrace-deposits of Utah; those, however, not having been so much interfered with by cultivation, are far more distinct. The loess here runs up to about 350 or 400 feet, and all cols or gaps between the hills above that height are free from it. Small streams flow down these valleys and meander across the plain, cutting deep into the superficial beds and exposing numerous fine sections.

The material hereabouts is a dark, bluish-brown, loamy clay, weathering yellowish-brown, often sufficiently sandy to form a good brick-earth, much used in the district. The burnt bricks are blue, red bricks being made by hydrating the ferric oxide, a process which simply consists in sprinkling the red-hot bricks with water.

The clay is stratified, the planes of deposition being marked by different shades of colour in some instances, more often by lines of pebbles where the deposit is close to the hills, and by the horizontality of the calcareous nodules which are locally known by the descriptive name of 'stone-ginger.' They are exactly comparable with the similar nodules of 'race' in the European loess.

The character of the local rocks has clearly impressed itself upon the deposit around Chefu, and save its tendency to split in vertical planes it bears very little resemblance to typical loess. At first we did not recognize it as such, but attributed it to local streams. It was not until we had mapped it, and followed it for long distances, that two facts dawned upon us: firstly, the impossibility of any stream, flowing through small land-locked valleys with very small

watersheds, depositing such vast thicknesses of débris; and secondly, the continuity of the mass over plain and valley alike, independent of any streams whatever. A very good example of such a land-locked valley is seen $1\frac{1}{2}$ mile south-west of Chefu. A glance at the map (fig. 2, p. 245)[1] shows that the catchment-basin of this little valley covers less than 2 square miles, yet the deposit in it is quite 100 feet thick.

The deposit bears evidence of vast superficial waste. It is eroded down to the bed-rock by the mountain-torrents, here as elsewhere in Shantung very intermittent, and the bare vertical sides of the resultant ravines which score the mass in every direction give a weird and unfinished aspect to the landscape. The pebbles occupy the lines of deposition, and, though in practically horizontal lines, are only subangular, and the first idea on seeing the mass was that it was an ordinary case of subaerial waste, the beds being deposited by mountain-torrents from the wreck of the older higher rocks.

Several considerations rendered this idea untenable. The first was the unmistakable level-line in which the débris terminated at its summit, some 300 feet above sea-level. Next was the insufficiency of the gathering-ground, the land never rising above 1400 feet, and the passes through which any streams have flowed being much lower, and in most cases quite close to, if not below, the level of the upper terrace, as in the case above cited. The valleys behind the hills south of Chefu also bore evident traces of having been more or less continuously filled with the deposit up to the same level, and no place existed for a large river flowing from higher levels.

Other reasons equally cogent pointed to a subaqueous origin. These were the level nature of the surfaces over which the parting gravels had been strewn, and the peculiar terraced character of the slopes to seaward, which (though partly artificial) must to some extent at least be referred to natural conditions. In this part of the province the sea has generally penetrated to the foot of the mountain-masses, and the terraced plains are reduced to modest dimensions, not more than a few square miles as a general rule.

On the north side of Chefu harbour rises a rocky mass known as the Bluff (see map, fig. 2, p. 245) of formation similar to that of the mainland, but remarkable for the fine development of its quartzites. It is slightly less than 2 miles distant from the port, and is now connected to the mainland by a narrow strip of shingle, only a few feet above high-tide mark. We found the superficial deposit exactly reproduced on the Bluff, and rising to approximatively the same level. Here the deposit could not be accounted for locally, as only a few points rose over the summit-level, and evidently it had once been connected with that of the mainland, forming a continuous whole.

Leaving Chefu, we started westward for Tsi-nan and, crossing a spur of the mountains, entered the plain through which the river Taku (long. E. 121° 17′) flows. The deposit formed a well-marked

[1] The valley is marked A.

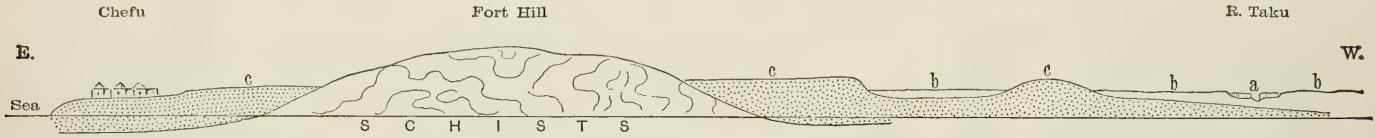
terrace to the west of Fort Hill, Chefu (fig. 3), and, having passed by some sand-dunes probably of the age of the Marine Sands, we came upon the plain of the Taku. We at first thought that this was composed of the alluvium of that river, but on reaching its banks we found the true alluvium to be very narrow (see fig. 4). We again went up on to the clay plains, and so journeyed as far as Sin Ho (lat. N. 36° 51′, long. E. 119° 34′).

As implied by its name, Sin Ho, or New River, is the termination of a canal, made in the 9th century to connect the Yellow Sea with the Gulf of Pe-chi-li, and so enable the rice tribute to be conveyed to Peking without necessitating the passage of the grain junks round the (to them) dangerous headlands of the Shantung Promontory (see map, fig. 1, p. 240). The canal started at Kyao Chow (lat. N. 36° 17′, long. E. 120° 2′), on the Yellow Sea, and thence led towards Kin Kia K'eo, in Lai Yang-hyien (lat. N. 36° 40′, long. E. 120° 50′). An intermediate branch followed apparently the line of the Wu Lung Ho, crossed the watershed and descended to Sin Ho, no part of its course being more than a very few feet above sea-level. The whole country which it traversed is a nearly level plain, and evidently in the Marine Sand period formed a strait, dividing the main area of Western Shantung from the islands which then represented the eastern prolongation of that province. The northern portion of this strait was about 30 miles wide, and a whole day was occupied in traversing its sands. At intervals the surface rose in long, low sand-ridges trending north-westerly, representing eddy-banks caused by the currents passing through the straits.

Reaching again the clayey deposits, which we had seldom lost sight of, on the other side of the old strait, we found that they had assumed the unmistakable character of genuine loess, and were divided into beds by layers of its characteristic calcareous nodules. We had first observed these nodules shortly after leaving Hwang Hyien (lat. N. 37°, long. E. 119° 40′), eastward of the old strait, but it was not till now that they had become characteristic, and that the loess changed its brown hue for the lighter yellowish-grey so marked to the westward. The change was so gradual and the sections were so nearly continuous that the identity of the loess with the Chefu deposit and the valley-deposit of the Taku was placed beyond question, and this was the more assured that in the sections here, as well as farther east, in following the loess down to the bed-rock the layer of gravel was found to be an invariable concomitant.

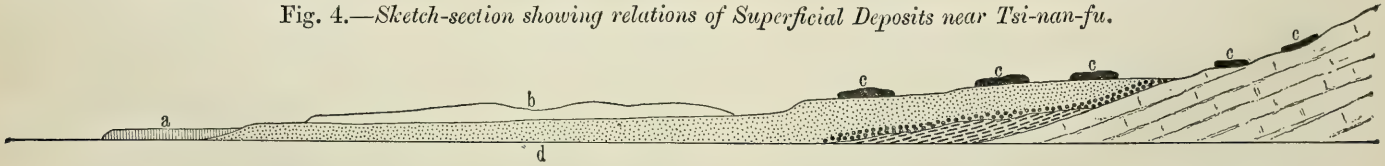
Still, though evidently loess, it was loess of a degenerate type, and bore plain traces of re-deposition and re-arrangement, which increased in clearness as we went on. The position of the old strait between Eastern and Western Shantung, and the occurrence of Marine Sands in its bed, showed moreover that the theory of a barrier between Shantung and Korea during the deposition of the old superficial beds around Chefu must be surrendered, and with it the suggested freshwater lake, for those deposits have turned out to be part of the great loess.

Fig. 3.—*Section from Chefu to the River Taku,* 9 miles.



The chief interest of this section lies in showing the relation of the undisturbed loess to the re-arranged loess, which was at first mistaken for alluvium of the Taku. A small outlier of undisturbed loess is seen to the east of the river, and the old terrace still farther east. *a*=Alluvium of River Taku; *b*=Re-arranged Loess; *c*=Undisturbed Loess.

Fig. 4.—*Sketch-section showing relations of Superficial Deposits near Tsi-nan-fu.*



a=Alluvium of modern rivers. *b*=Marine Sands. *c*=Patches of old Valley-gravels. *d*=Loess.

From Hwang Hyien westwards the same story was repeated, and to describe in detail every separate exposure would be unprofitably tedious.

While accepting with all its concomitant consequences a marine origin for that loess with which the authors are most intimately acquainted, and, as a necessary corollary, for the entire loess of Asia, it would be an error to suppose that the loess as it at present exists owes its formation universally, or even generally, to submarine conditions. Nothing is more marked, especially in Shantung, than the enormous amount of denudation and subsequent redistribution to which it has, under subaerial conditions, been subjected, and it is this fact which has led to so many erroneous conclusions. We have spoken of the loess after crossing the strait at Sin Ho as 'degenerate,' in this sense, that it is the remains of a former thick covering, now reduced in dimensions, and in great part re-arranged. This indeed is the characteristic feature of the formation in the prefectures of Lai-chow, Ts'ing-chow, and part of Tsi-nan-fu (lat. N. 36°–37°, long. E. 117°–119°), north and west of which it descends under the Marine Sands of Wu-ting (lat. N. 37°, long. E. 118°), Tung-chang (lat. N. 36° 40′, long. E. 116° 20′), and the north of Tsi-nan-fu. Its former greater extension is shown there by the remains of rolled pebbles formed of the characteristic nodules, which are to be found strewn over the hillsides to a height of upwards of 500 feet, and by the occurrence of patches of loess remaining in sheltered nooks, as in a patch by the side of the gap above the K'ai Yuen temple, a few miles south of Tsi-nan city, at an altitude of 600 feet.

If marine shells are absent from the loess, we are not without some slender evidence of their former existence. The rocks about the K'ai Yuen temple bear evident traces of *Pholas*-borings wherever the loess has been denuded and the rock laid bare; and a ledge of hard limestone (Carboniferous) about 7 miles south-east of Tsi-nan, some 500 feet above sea-level and protected by a projecting ledge from weathering, might have been exposed but yesterday, so fresh are the borings. From a specimen taken away, what appeared to be a small papery fragment of the original shell was obtained.

II. The Basement-gravels.

Wherever the base of the loess is exposed it is seen, almost invariably, to repose upon sands, gravels, and shingle, as we have observed over an area of about 600 by 700 miles, in the provinces of Kiangsu, Anhwei, Honan, Shanse, Shantung, and Pe-chi-li.

We have then, in this as in other observations connected with the loess, to deal with no isolated fact, but with phenomena extending over a great continent; and it is this that has rendered generalization so difficult. If the marine origin of the loess be conceded, many of these gravels will be seen to be remains of beaches of the old loess sea.

The stones, where we have examined them, are rolled and water-worn, very different from the torrent-débris of the present streams; and they are, as might be expected, chiefly of local origin: schists, gneiss, and quartzites in the Archæan region, sandstones and limestone in the Carboniferous area.

In Europe, especially in England and France, what are usually classed as loess-beds often lie upon true river-gravels, as is the case with the Thames and the Somme. We are inclined to think that much of this material is not true undisturbed loess (as is shown by its sweeping down the valley-sides and not lying like a flat cake), but that it is either of different origin, or re-arranged as is so much of the loess of China. Nevertheless, if the loess has been deposited tranquilly in a quiet sea not very unlike the present Yellow Sea and Gulf of Pe-chi-li, during a gradual submergence, the river-gravels of the sinking land would be covered up, as doubtless some of the old valley-gravels of Shantung are by the Marine Sand.

In Europe traces of man's handiwork are found associated with the loess; in China up to the present this is not so, and our searches were fruitless, but as yet hardly a single observer has dealt with this question in China. A few prehistoric stone-implements are known, but all are of far more recent date than the loess.[1]

We look upon the Basement-gravels as being to the loess sea very much what the Upper Greensand was to the Chalk sea—a series of beaches extending their limits as the sea-waters crept onward during slow subsidence.

III. The Tertiary History of North China.

Comparatively little is known of the Tertiary formations of North China, but in the provinces of Chekiang and Kiangsu the following may be noted.

Beginning at Ning-kong-jow (lat. N. 29° 45′, long. E. 121° 30′), some 12 miles from Ningpo, is a very marked series of flagstones. Commencing in rough shingles, almost boulder-beds, some of the fragments having a cubical content of 6 to 8 feet, they pass upwards into fine siliceous flagstones. These, not improbably representatives of the Siwalik Sandstones of India, though as yet they have apparently yielded no fossils, are probably slightly over 1000 feet in thickness. They are associated with or underlie an equally thick mass of volcanic tuffs, locally called the Daying Beds. Succeeding these, apparently, are a series of red sandstones, characteristic about Hang-chow (lat. N. 30° 15′, long. E. 120° 30′), which may conveniently be called 'the Hang-chow Sandstones.' These are largely represented in the valley of the Yangtse, appearing about Nanking and still higher up in Kiangsi and Hupeh, and at Hankow (lat. N. 30° 35′, long. E. 114° 25′) are largely used for building purposes.

Following these again is a thick series of siliceous gravels,

[1] *Cf.* Evans, 'Stone Implements,' pp. 103, 116; Southall, 'Rec. Orig. Man,' p. 391; Skertchly, 'Across Shantung,' Hongkong, 1892, pp. 5, 6.

evidently marine in origin, apparently once widely spread, but now principally confined to the neighbourhood of Nanking and Chin-kiang (lat. N. 32° 20′, long. E. 119° 30′).

The ancient rocks of the Yangtse valley are for the most part Carboniferous, but passing down to Devonian and probably Silurian. They were formerly capped by the upper coal-bearing sandstones, but these were in comparatively early times removed by denudation, except in a few isolated patches, and not improbably the red Hang-chow Sandstones are the result. Everywhere along the Yangtse, from Western Szechuen to Chinkiang, the Carboniferous Limestone is the prevailing rock where the Palæozoic strata are exposed, and it preserves throughout a remarkable similarity in structure and composition. Certain of its beds are marked by the occurrence of large masses of chert, the remains of siliceous sponges, and these are usually accompanied by the characteristic shells of the deposit, *Spirifer*, *Rhynchonella*, etc., as well as by the remains of corals.

The siliceous gravels, which from their being characteristic at this spot near Nanking we may call the Yü-hwa-t'ai (lat. N. 32° 1′, long. E. 119° 5′) Gravels, are the remains of the slow denudation, under aqueous conditions, of the Carboniferous Limestone. They are, in fact, entirely composed of the ancient chert-sponges, worn down and rounded, but marked by the contained fossils; and, though they attain a thickness of several hundred feet, not the smallest particle of the limestone-matrix can be discovered in the mass, it having been entirely removed in solution.

The period of deposition of these gravels ended with an outburst of volcanic activity in the region of Lower Kiangsu at least. Violent eruptions on a large scale threw out wide sheets of basaltic lavas, occasionally assuming columnar structure, while in places volcanic cones still cap the gravels. To this outburst we apparently owe the preservation of such portions of the gravels as still exist.

Although these later rocks have hitherto proved barren of fossils, the cause is probably inadequate search. They are, however, distinctly marine, and it may be assumed that the greater part of North China was at this period covered by the ocean. We speak with some degree of diffidence, but there seems evidence for connecting these beds with the pre-loess deposits of Eastern Turkestan and the Upper Oxus. However it happened, the way was prepared for the deposit of the loess: most probably a gradually rising land altered the currents, and converted an open into a more or less land-locked muddy sea. The loess, in Kiangsu at all events, immediately succeeds the basaltic flows, and is to be found capping the thick masses. The beginning of the period was probably, however, accompanied by a sinking which allowed for the formation of the fringing beach already spoken of; but this sinking was doubtless in no case much more than 1000 feet and in most places much less, and ended in a long period of rest during which the loess was deposited to a depth in Shantung of a little over 500 feet, in Kiangsu to about 400 feet, and in Shanse and the west probably 1500 to 2000 feet.

Then ensued partial elevation, with the formation of the Marine Sands and old Valley-gravels, and this probably continued till the land assumed its present contours.

The beds, so far as at present known, are as follows, numbered in ascending order :—

9. Modern Alluvium.		
8. Marine Sands;	} Contemporaneous.	
7. Old Valley-gravels.		
6. Loess;	} Contemporaneous in part.	
5. Basement-gravels.		
4. Basalt-flows of Kiangsu.		
3. Yü-hwa-t'ai Gravels.		
2. Daying Beds, volcanic.		
1. Hang-chow Sandstones.		

IV. Conclusions.

The conclusions at which we have arrived are the following :—

1. Northern and Eastern Asia have never been glaciated in the same sense that Europe has, hence the loess is in no way connected with glacial action.

2. The loess, where undisturbed, shows very plain evidence of stratification.

3. It is certainly not of æolian formation, but is as certainly an aqueous deposit, and, from the enormous difficulties in accepting a freshwater origin, we have been driven to ascribe to it a marine origin.

4. Its vast extent, probably over 1,000,000 square miles in China alone, entitles it to rank among the great formations of the world.

5. It has suffered enormous denudation and re-arrangement.

6. It is succeeded by very extensive Marine Sands, and old Valley-gravels.

7. Zoological, ethnological, historical, and traditionary evidence alike point to the former depression of Asia beneath the sea, and the subsequent desiccation of the land consequent upon re-elevation.

Discussion.

Dr. W. F. Hume remarked that the difficulties in accepting the theory are almost insuperable. The fact that Baron von Richthofen's theory had not been fully discussed was a serious feature in the paper. The perfect preservation of land-shells and mammalia, the irregular vertical distribution, and the absence of limestones and marine shells alike disprove the view brought forward by the Authors.

Mr. Marr thought that the Authors should have paid more attention to the views of Baron von Richthofen, and the evidence of Nehring, which had been summarized in the 'Geological Magazine,' since the paper of one of the Authors published in the Society's Journal in 1871.

Dr. Du Riche Preller agreed with Dr. Hume that the hypothesis of the Authors as to the China loess having no connexion with any area of glaciation was quite untenable. As in the case of the Don loess in Russia, so also in that of the Swiss and Rhenish loess, there was no doubt of its being in the main of glacial origin—to wit, it was moraine transported and re-arranged by glacier-streams, that is by fluviatile agency, and was subsequently, probably in an interglacial period, re-deposited by æolian action. The theory of the Authors as to the China loess being a marine formation was manifestly vitiated by their own somewhat hazardous conjecture that the marine shells had simply disappeared.

Mr. Clement Reid expressed his regret that there were no specimens on the table.

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[The Editor of the Quarterly Journal is directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

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Vol. LI. AUGUST 1st, 1895. **No. 203.**
PART 3.

THE

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OF THE

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„ June 10–24

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22. Contributions *to the* Palæontology *and* Physical Geology *of the* West Indies.

By J. W. Gregory, D.Sc., F.G.S. (Read February 20th, 1895.)

[Plate XI.]

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I. Introduction.

Shortly after Mr. Jukes-Browne's return from Barbados in 1889, he asked me to identify a collection of fossil corals which he had made on that island. A very cursory examination showed that the synonymy of the coral fauna of the West Indies was in such confusion that it would be impossible properly to execute this task, and work out the relations of these Barbadian fossils, with the material then available to me. The causes of the difficulty were as follows:—In the West Indies there are two coral faunas, one recent and the other fossil. The former has been described by the neontologists, the latter by the palæontologists; and neither school has devoted adequate attention to the work of the other. If the two faunas had been wholly distinct, this would not have mattered so much; but unfortunately they overlap, and thus the same species have been twice described. The extent to which this has been carried has been greatly increased by the fact that many late Pleistocene species have been mixed in collections with those of the older Kainozoic deposits. The synonymy has been still further complicated by the imperfection of the original figures and descriptions upon which most of the species are based. The West Indian corals were favourite objects in the collections of the early naturalists, and thus the great majority of the species date back to the works of the museographers of the last century. The illustrations given by these authors show the mode of growth and general appearance of the corals, but the generic characters are often unrecognizable. It is, therefore, not surprising that very different interpretations have been placed upon them.

To overcome these difficulties it was necessary to obtain a collection of specimens from the reefs of the district whence the fossils had come, and to cut sections of these so as to be able to institute a comparison on equal terms. It was also necessary to examine the types of the recent species described by the neonto-

logists. The chief of these were those of Duchassaing and Michelotti now preserved in the Museum of the Royal University of Turin, of Milne-Edwards and Haime in Paris, of Verrill in New Haven (Connecticut), of Pourtalès in the Museum of Comparative Zoology in Cambridge (Mass.), and of various West Indian expeditions in the Museums at Washington (D. C.). The study of these types was rendered possible by the kindness of the Trustees of the British Museum, who, on the recommendation of Dr. H. Woodward, F.R.S., granted me an extra leave of absence in 1891, in order to visit the principal American collections. To the officials of these Museums I am most grateful for their kind help, especially to Prof. A. Agassiz, who allowed me free access to the rich collections of the Museum of Comparative Zoology, in spite of the inconveniences entailed by a visit during the summer vacation. I am also greatly indebted to Prof. Sacco for his assistance during an examination of Duchassaing and Michelotti's types; these authors so seldom figured, and so briefly described, the numerous species which they founded, that without a study of their types it would have been impossible to include their names in the synonymy.

The most important collection of the fossil corals is that described by the late Prof. P. M. Duncan in five valuable papers on 'the Fossil Corals of the West Indies.' Most of the specimens he described are now preserved in the Museum of the Geological Society, and the rest are mainly in the British Museum. The collection is therefore readily accessible: by permission of the Council of this Society several of the types have been cut, and thus some doubtful structures determined. I desire to express my thanks to the Assistant Librarian, Mr. W. Rupert Jones, for the help which he has so readily given me during the examination of this collection. Unfortunately the specimens were not collected with as much care as that devoted to their description; mixed up with Miocene and Oligocene species, there are many derived from late Pleistocene reefs. That this circumstance escaped Duncan's notice, although he remarked their association with Pleistocene mollusca, is doubtless due to the intense alteration which they have often undergone. Many of the corals are more changed and less recognizable than ordinary Silurian specimens; this therefore gives them an aspect of great age, which is strengthened by their affinity to the extinct species of the Mediterranean Miocene. But it often happens that one half of a specimen from the recent reefs of the West Indies may be altered into chalcedony without any trace of coral-structure left, while the other shows every detail in perfect preservation.

Little, therefore, could have been done without further collections from Barbados. The greatest thanks are due to Mr. G. Firth Franks, F.G.S., then of the Harrison College, Barbados, who, at the request of Mr. Jukes-Browne, devoted much time and expense to the formation of collections from the recent and fossil reefs of the island. This collection he has generously presented to the British Museum (Natural History), and it forms the main basis of the present paper. Mr. Jukes-Browne has also presented his collection,

which is of value, as it contains many specimens in excellent preservation from the High-level Reefs. Col. H. W. Feilden also grasped the importance of the study of the fauna of the oldest raised reefs, and collected some specimens from the highest available points; these are unfortunately in imperfect preservation, but are of value from the care with which the altitudes have been recorded. C. E. Easton, Esq., C.E., has also presented to the British Museum a large series of specimens from various shafts and tunnels made by him for the Barbados Waterworks Co. Finally the Rt. Rev. Bishop Mitchinson has given to the British Museum a collection of over a thousand specimens of mollusca from the Low-level Reefs near Bridgetown. These are recorded in the third part of the present paper.

I must apologize, to those who have so generously helped with material, for the long delay in the completion of this paper. The part dealing with the corals was finished in the autumn of 1892, and was then ready for publication. The manuscript was, however, stolen a few months later when my luggage was looted on the eastern coast of Africa. As the notes on the Paris types were lost at the same time, it has been necessary to leave out references to many of the species—especially of *Mœandrina*—founded by Milne-Edwards and Haime, which I believe to be only synonyms.

II. The Corals of the Raised Reefs of Barbados.

Considering the confusion in the synonymy of the West Indian Corals, a mere list of species would be useless. The synonymy of the species is therefore given in some detail, in order that the value assigned to each may be easily recognized.

The classification adopted is that of Duncan's 'Revision of the Madreporaria,'[1] as this is still the most convenient for systematists. The later schemes of Ortmann[2] may have a more scientific basis, but at present they are not in a form that can be recommended for general adoption. A classification that unites *Lithophyllia*, *Mussa*, *Symphyllia*, and *Diploria* into one family and then places *Mussa Harti*, *Eusmilia*, and *Euphyllia* in a different order; which places *Oculina* and *Heliastræa* in one family and separates *Pectinia* and *Manicina* into different orders, is too revolutionary to be accepted without much further evidence in its support. At present it seems very like a *reductio ad absurdum* of the principles on which it is based.

[1] Journ. Linn. Soc., Zool. vol. xviii. (1884) pp. 1–204.

[2] 'Beobachtungen an Steinkorallen von der Südküste Ceylons,' Zool. Jahrb. vol. iv. (1889), Abt. f. Syst. pp. 548–554, and 'Die Morphologie des Skelettes der Steinkorallen in Beziehung zur Koloniebildung,' Zeitschr. f. wiss. Zool. vol. l. (1890) pp. 314, 315.

Order **MADREPORARIA.** Suborder **APOROSA.**

Family OCULINIDÆ.

Genus MADRACIS, M.-Ed. & H., 1849.

Syn. *Reussia*, Duch. & Mich.; *Pentalophora*, Sav. Kent; *Axohelia*, M.-Ed. & H.

Species MADRACIS DECACTIS (Lyman).

Synonymy:—

Astræa decactis, Lyman, 1859, 'New Sp. Coral.' Proc. Bost. Soc. Nat. Hist. vol. vi. pp. 260–263.

Madracis decactis, Verrill, 1864, 'List of Corals sent etc.' Bull. Mus. Comp. Zool. vol. i. p. 45; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. pp. 28 & 67; *id.* 1874, 'Hassler Corals,' *ibid.* no. viii. p. 41; Lindström, 1877, 'Actin. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 15; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exp. pt. xlvi. p. 53.

Reussia lamellosa, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 339, pl. ix. fig. 8; *iid.* 1866, 'Suppl. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 164; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 26.

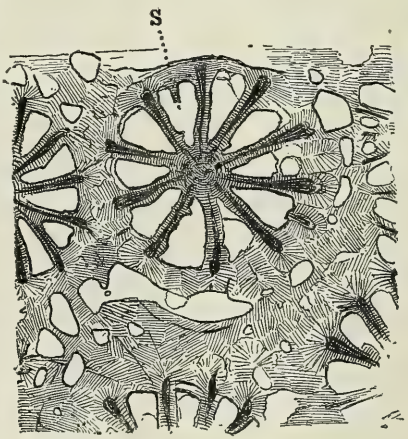
Stephanocœnia dendroidea, non M.-Edw. & H., Duncan, 1863, 'W. Ind. Cor.' pt. i. Quart. Journ. Geol. Soc. vol. xix. p. 432.

? *Stylophora minuta*, Duncan, 1868, 'W. Ind. Cor.' pt. iv. *ibid.* vol. xxiv. p. 14.

Distribution. Recent: St. Thomas, Barbados, Florida (6–17 faths.), Bermuda. *Fossil*: Pleistocene, Bermuda (Coll. Geol. Soc.); Barbados: Low-level Reefs (B.M. Coll. Presented by G. F. Franks, Esq.); San Domingo: Nivajé & Cerro Gordo Shales (Coll. Geol. Soc.).

Notes on the Species.—The genus is said by Duncan to have no costæ, while both he and Milne-Edwards & Haime in their original diagnosis state that the septa are all of uniform size. This was one of its differences from the nearly allied *Stylophora*. Some sections, however, cut from the specimens from Barbados, show that a rudimentary set of septa and also costæ may be sometimes present (see fig. 1). Quelch includes Duchassaing & Michelotti's species *Stylophora incrustans* as a synonym of this; but the figure is useless, and I did not see the type at Turin. The type of Duncan's *S. minuta* was lost, and so the value of this species cannot be determined; the two specimens identified by that author as *Stephanocœnia dendroidea* are both in the Society's Museum; they certainly belong to *Madracis*, and appear to be only a form of *M. decactis*, which grows out into low, cylindrical, massive branches.

Fig. 1.—*Section of* Madracis decactis (*Lym.*). (×*12 diam.*)



To show rudimentary septum (S).

Family ASTRÆIDÆ.

Subfamily Astræidæ simplices.

Genus Lithophyllia, M.-Ed. & H., 1857.

Species 1. Lithophyllia lacera (Pallas), 1766.

Synonymy:—

Madrepora lacera, Pallas, 1766, 'Elench. Zooph.' pp. 298–299; Esper, 1789, 'Pflanzenth.' Bd. i. pp. 148–150, pl. xxv. fig. 2.

Caryophyllia lacera, var. *a*, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 316; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 237; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 72.

Lithophyllia lacera, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 291; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 343; *iid.* 1866, 'Suppl. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 170; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12; Ortmann, 1890, 'Morph. Skel. Steinkor.' Zeit. wiss. Zool. Bd. l. p. 291.

Caryophyllia carduus pars, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 229; *id.* 1836, 'Hist. Nat.' ed. 2, t. ii. p. 357.

Lithophyllia Argemone, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 344, pl. ix. fig. 12, pl. x. fig. 15; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 171; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28.

Lithophyllia cylindrica, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 344, pl. ix. figs. 17, 18; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* t. xxiii. p. 171; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28; Quelch, 1886, Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Lithophyllia radians, Duchassaing & Michelotti, 1866, *op. jam cit.* p. 171, pl. vii. figs. 3, 4; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28; Quelch, 1886, *op. cit.* p. 12.

Distribution. *Recent*: West Indies; Florida. *Fossil*: Barbados: Low-level Reefs.

Species 2. Lithophyllia cubensis (M.-Ed. & H.).

Synonymy:—

Caryophyllia cubensis, M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. ser. 3, t. xi. p. 238.

Lithophyllia cubensis, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 292; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 343, pl. v. fig. 10; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 170; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 70; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Lithophyllia dubia, Duchassaing & Michelotti, 1861, *op. jam cit.* p. 344, pl. ix. fig. 15; *iid.* 1866, *op. jam cit.* p. 171; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 70; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Lithophyllia multilamellosa, Duchassaing & Michelotti, 1866, Suppl., *op. jam cit.* p. 171, pl. viii. fig. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 28.

Montlivaltia ponderosa, non M.-Edw. & Haime, Duncan, 1863, 'West Ind. Cor.' pt. i., Quart. Journ. Geol. Soc. vol. xix. pp. 441, 442, pl. xvi. fig. 6.

Antillia ponderosa, non M.-Edw. & Haime, Duncan, 1864, 'West Ind. Cor.' pt. ii. *ibid.* vol. xx. p. 28, pl. v. fig. 5; *id.* 1868, 'West Ind. Cor.' pt. iv. *ibid.* vol. xxiv. p. 23.

Antillia explanata, Pourtalès, 1874, 'Hassler Corals,' Ill. Cat. Mus. Comp. Zool. no. viii. p. 42, pl. vii. figs. 4–6; A. Agassiz, 1888, 'Three Cruises of the 'Blake,'' Bull. Mus. Comp. Zool. vol. xv. p. 154, fig. 478.

Distribution. *Recent*: West Indies; Florida. *Fossil*: Barbados: Low-level Reefs; Jamaica.

Notes on the Species.—The *Lithophyllia multilamellosa* of Duchassaing & Michelotti is shown by the figure which they give to be very closely allied to the type-form. The figure of their *L. dubia*

appears more divergent owing to the thinness of the septa. The type of this species is, however, in Turin, and shows that the septa of the first two cycles are of the normal thickness; the examination of the type left no doubt as to the species being the same as that of Milne-Edwards & Haime.

The inclusion in the list of synonyms of a species which Duncan assigned to *Antillia* renders necessary a remark on this genus, and on the value of the epitheca in this group. The genus was founded by Duncan in 1864; he included in it a series of species agreeing in having an essential columella and a membraniform epitheca. The septa and costæ are of two types: in some species, as in his type-species *A. ponderosa*, the septa are not lobed and the costæ are coarsely dentate; in other species, such as *A. Lonsdaleia*, the septa are lobed and the costæ finely granulate. In his 'Revision' (p. 60) he reduces the genus to a subgenus of *Circophyllia*, and still bases its value on the epitheca.

The examination of a considerable series of specimens shows, however, that the epitheca is so very variable in this group that it does not appear worthy of even subgeneric value; the characters of the septa and costæ seem much more important. In some specimens the epitheca is present and in others quite rudimentary, and all stages can be seen between the two conditions. In this case the genus has to be split up into two. Duncan's type goes into *Lithophyllia*, and the *A. Lonsdaleia* and some others into *Circophyllia*.

Milne-Edwards & Haime's *M. ponderosa* seems to me a different species from that which Duncan has assigned to it. It is well figured in the atlas to the 'Histoire Naturelle des Coralliaires,' pl. D. iii. fig. 2. It appears to me that Duncan's *A. bilobata* is the same as the true *M. ponderosa*, Ed. & H., and the *M. Guesdesi*, Duch. & Mich. In the specimens figured by Duncan and by Duchassaing & Michelotti the shape of the corals is bilobed; but this is only an individual character, for in the series of specimens in the British Museum collection several are regularly elliptical.

Species 3. Lithophyllia Walli (Duncan).

Synonymy:—

Antillia Walli, Duncan, 1865, 'Foss. Corals Jamaica,' Quart. Journ. Geol. Soc. vol. xxi. p. 11, pl. ii. fig. 4.

Distribution. *Fossil*: Pleistocene? Bowden, Jamaica (type in Geol. Soc. Mus.). Barbados: Low-level Reefs (B. M. R 1284).

Subfamily Astræidæ cæspitosæ.

Genus Eusmilia, M.-Edwards & Haime, 1848, em. 1857.

Species 1. Eusmilia fastigiata (Pallas), 1766.

Synonymy:—

Madrepora fastigiata, Pallas, 1766, 'Elench. Zooph.' p. 301; Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1280.

* *Madrepora fastigiata*, Ellis & Solander, 1786, 'Hist. Nat. Zooph.' p. 152, pl. xxxiii.; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3777.

Mussa fastigiata, Oken, 1815, 'Lehrb. Naturg.' Zool. Bd. i. p. 73; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. pp. 175, 720.

**Caryophyllia fastigiata*, Lamarck, 1816, 'Hist. Anim. s. Vert.' t. ii. pp. 228, 229; Lamouroux, 1821, 'Exp. Méth. Polyp.' p. 50, pl. xxxiii.; *id.* 1824, 'Encycl. Méth. Zooph.' p. 172.

Caryophyllia fastigiata, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berl. 1832, p. 316.

* *Caryophyllia fastigiata*, Lamarck, 1836, 'Hist. Anim. s. Vert.' ed. 2, t. ii. p. 355.

Caryophyllia fastigiata, Schomburgk, 1847, 'Hist. Barbados,' p. 562.

Lithodendron fastigiatum, Schweigger, 1820, 'Handb. Naturg.' p. 416.

* *Lobophyllia fastigiata*, Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 321; id. 1834, 'Man. Act.' p. 356; Duchassaing, 1850, 'Anim. rad. Ant.' p. 15; id. 1855, 'Form. Mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. p. 756.

Eusmilia fastigiata, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat., Zool. sér. 3, t. x. p. 264, pl. v. fig. 1; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 52; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 187; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 340; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 165; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 67; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 167.

* *Madrepora capitata*, var., Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. p. 102, pl. Madrep. lxxxii.

* *Lithodendron capitatum*, Schweigger, 1820, 'Handb. Naturg.' p. 416.

Eusmilia Silene, Duchassaing & Michelotti, 1861, *op. supra cit.* ser. 2, t. xix. pp. 340, 341, pl. x. figs. 11, 12; *iid.* 1866, Suppl., *op. supra cit.* ser. 2, t. xxiii. p. 165; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Quelch, 1886, *op. supra cit.* pt. xlvi. p. 12.

Eusmilia alticostata, non M.-Ed. & H., Pourtalès, 1871, *op. supra cit.* p. 68.

Distribution. Recent: West Indies, Florida. *Fossil*: Barbados: Low-level Reefs, Bridgetown; High-level Reefs, Castle Grant, 1050 feet (Jukes-Browne Coll.); Guadeloupe: Tuf blanc.

Species 2. Eusmilia Knorri, M.-Edwards & Haime, 1848.

Synonymy:—

Eusmilia Knorri, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 265, pl. v. fig. 2.

Madrepora capitata, Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. p. 102, pl. Madrep. lxxxi. (*non* var. pl. lxxxii.).

Euphyllia aspera, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. pp. 164, 720, pl. ix. fig. 7.

Eusmilia aspera, M.-Edwards & Haime, 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 52; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. pp. 187, 188; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 340; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 165; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 167.

Eusmilia alticostata, M.-Edwards & Haime, 1848, *op. supra cit.* Ann. Sci. Nat. Zool. sér. 3, t. x. p. 265; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 188.

Distribution. Recent: West Indies. *Fossil*: Pleistocene, Low-level Reefs, Bridgetown, Barbados (Franks Coll. & Old Coll. B.M.).

Notes on Synonymy.—The synonymy of these two species of *Eusmilia* has been very confused, as they have been separated at different times on two different and discordant characters. Their distinction is here based on the structure of the columella. This is well developed in *E. Knorri* (see figures of Milne-Edwards & Haime and of Esper), and very imperfectly so in *E. fastigiata*. This character has, however, often been ignored, and the distinction has then been based on the development of the epitheca, which seems to me to be useless.

Unfortunately we do not definitely know the nature of the columella in Pallas's type, but he describes his species as with 'centrum immersum, exiguum, cellulosum.' This would seem to

indicate an imperfect development of the columella. If it is not so, then Pallas's species is not the *fastigiata* of all later authors, but is the *E. Knorri* of Milne-Edwards & Haime, and the *E. aspera* of Dana. Milne-Edwards & Haime separate the *fastigiata* of Ellis & Solander from that of Pallas, and make it a synonym of *E. Knorri*. If this be the case, then all those references in the synonymy of *E. fastigiata* marked by an asterisk must be transferred to *E. Knorri*; but there seems to me no reason why this should be done, for they are all based on a figure in which the columella is not shown; so far as the evidence of the figure goes, one would infer from the aspect of the calices that the columella was most imperfect. The reason that apparently led Milne-Edwards & Haime to suggest this confusion of the synonymy was the character of the costæ and epitheca.

In regard to the name for the second species, I think that the safest course is to take that of Milne-Edwards & Haime, which was accurately diagnosed and figured, instead of the earlier ones of Esper and Dana. Esper included under *capitata* two species; it is impossible to remove all doubt as to whether his typical form is *fastigiata* or *Knorri*. Dana's species was also so inadequately diagnosed that there can be no certainty regarding it. He makes it a synonym of both the *C. fastigiata* of Lamarck and the *M. capitata* of Esper (pl. lxxxi.); one of these must be incorrect. Milne-Edwards & Haime regard Dana's *Mussa fastigiata* and his *Euphyllia aspera* as the same species.

Milne-Edwards & Haime diagnosed both species very well, and it seems best to accept them as thus defined, but not to follow these authors in their synonymy.

Genus Mussa, Oken, 1815, em. Dana 1846.

Species Mussa angulosa (Pallas), 1766.

Synonymy:—

Madrepora angulosa, Pallas, 1766, 'Elench. Zooph.' pp. 299–300; Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 152, pl. xxxiv.; Esper, 1788, 'Pflanzenth.' Bd. i. pp. 92–95, pl. Madrep. vii.; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3781.

Mussa angulosa, Oken, 1815, 'Lehrb. Naturg.' Zool. Bd. i. p. 73; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. pp. 176–177, pl. viii. fig. 4; M.-Edwards & Haime, 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 78; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. pp. 329–330; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 345; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. pp. 158, 172; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 72; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 168.

Caryophyllia angulosa, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 229; Lamouroux, 1824, 'Encycl. Méth. Zooph.' p. 173; (pars) Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berl. 1832, p. 315; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, p. 355.

Lithodendron angulosum, Schweigger, 1820, 'Handb. Naturg.' p. 416.

Lobophyllia angulosa, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 321; *id.* 1834, 'Man. Act.' p. 355, *non* pl. liii. fig. 3; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 245.

Caryophyllia dubia, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 335, pl. v. fig. 2.

Distribution. *Recent*: West Indies. *Fossil*: Barbados: Low-level Reefs (Franks Coll.).

Subfamily Astræidæ confluentes.

Genus Dendrogyra, Ehrenberg, 1834.

Species Dendrogyra cylindrus, Ehrenberg.

Synonymy:—

(*Mæandrina*) *Dendrogyra cylindrus*, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 324.

Dendrogyra cylindrus, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 280, pl. vi, figs. 9, 9 *a*; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 55; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 202; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 341; *iid.* 1866, 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 165; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 69.

Meandrina cylindrus, Dana, 1848, 'Zooph. Expl. Exped. Wilkes,' vol. viii. p. 265.

Dendrogyra Sancti-Hilarii, Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' *op. jam cit.* p. 166; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27.

Distribution. *Recent*: West Indies. *Fossil*: Low-level Reefs, Barbados (Franks Coll.).

Genus Pectinia, Oken, 1815 (em. M.-Edwards & Haime, 1851).

Species Pectinia mæandrites (Pallas), 1766.

Synonymy:—

Madrepora mæandrites, Pallas, 1766, 'Elench. Zooph.' pp. 292–294; Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1274; Maratti, 1776, 'De Plant. Zooph. et Lithoph.' p. 47; Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 161, pl. xlviii. fig. 1.

Madrepora mæandrites (pars), Esper, 1788, 'Pflanzenth.' pp. 76–84, pl. iv. A, *non* pl. iv.; Gmelin, 1790, 'Linn. Syst. Nat.' ed. xiii. p. 3761.

Madrepora mæandrites, var., Esper, 1795, 'Pflanzenth.' Fortsetz. p. 101, pl. lxxx. fig. 2.

Mæandra mæandrites, Oken, 1815, 'Lehrb. Naturg. Zool.' Bd. i. p. 70.

Ctenophylla mæandrites, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 277.

Pectinia mæandrites, M.-Edwards & Haime, 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 57; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 207; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 342; *iid.* 1866, Suppl., *ibid.* ser. 2, t. xxiii. p. 168; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 68; Lindström, 1877, 'Cont. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 22.

Manicina mæandrites, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 326.

Mæandrina pectinata, Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 372; *id.* 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 247.

Mæandrina pectinata (pars), Lamouroux, 1821, 'Exp. Méth.' p. 55, pl. xlviii. fig. 1 (*non* pl. li. fig. 1).

Mæandrina pectinata, Blainville, 1823, 'Méandrine,' Dict. Sci. Nat. t. xxix. p. 376; Deslongchamps, 1824, 'Encycl. Méth. Zooph.' p. 508, pl. 485. fig. 1; Eichwald, 1829, 'Zool. Spec.' pars i. p. 185; Blainville, 1830, 'Zoophytes,' Dict. Sci. Nat. t. lx. p. 322; *id.* 1834, 'Man. Act.' p. 357; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 387; Duchassaing, 1850, 'Anim. rad. Ant.' p. 16.

Pectinia pectinata, Oken, 1815, 'Lehrb. Naturg. Zool.' t. i. p. 68.

Manicina pectinata, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 326.

Ctenophyllia pectinata, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 170, pl. xiv. fig. 13.

Madrepora labyrinthica (pars), Pallas, 1766, 'Elench. Zooph.' pp. 297–298.

Ctenophyllia quadrata, Dana, 1848, *op. supra cit.* p. 171, pl. xiv. fig. 14; M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 278.

Pectinia quadrata, M.-Edwards & Haime, 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 57; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 209; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 342; *iid.* 1866, 'Suppl. etc.' *ibid.* ser. 2, t. xxiii. p. 168; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27.

Pectinia disticha, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' *op. cit.* p. 342, pl. ix. fig. 16; *iid.* 1866, 'Suppl. etc.' *op. cit.* p. 168; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27.

Pectinia elegans, Duchassaing & Michelotti, 1861, *op. cit.* p. 342; *iid.* 1866, p. 168; Duchassaing, 1870, p. 27.

Pectinia caribæa, Duchassaing & Michelotti, 1861, *op. cit.* p. 343; *iid.* 1866, p. 168; Duchassaing, 1870, p. 27.

Manicina areolata (non auct.), A. Agassiz, 1890, 'Growth of Corals,' Bull. Mus. Comp. Zool. vol. xx. no. 2, p. 62, pl. iii.

Distribution. Recent: West Indies. *Fossil*: Low-level Reefs, near Bridgetown, Barbados (Franks Coll.).

Notes.—*Pectinia quadrata* seems to be clearly only a young form; *P. elegans* must go with *P. quadrata*. A certain amount of confusion has been caused by Esper having included in his *M. mœandrites* two different species: one (pl. iv. A) is clearly the type-form, but the other (pl. iv.) has been generally regarded as a *Manicina areolata*; several later authors have taken the wrong form as the type, while recently the converse error has been made.

Genus Diploria, M.-Edwards & Haime, 1848.

Species Diploria cerebriformis (Lamarck), 1816.

Synonymy:—

Mœandrina cerebriformis, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 246; Blainville, 1823, 'Méandrine,' Dict. Sci. Nat. t. xxix. p. 376; Deslongchamps, 1824, Encycl. Méth., 'Zooph.' p. 508; Blainville, 1830, 'Zoophyte,' Dict. Sci. Nat. t. lx. p. 323; *id.* 1834, 'Man. Act.' p. 357; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 386; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 263, pl. xiv. fig. 2; Duchassaing, 1850, 'Anim. rad. Ant.' p. 16.

Mœandrina (*Platygyra*) *cerebriformis*, var. *a*, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 324.

Diploria cerebriformis, M.-Edwards & Haime, 1848, 'Classif. deux. tribu Astr.' Compt. Rend. t. xxvii. p. 493; *iid.* 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 289; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 92; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 402; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 351; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. t. i. p. 48; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 176; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 75; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet. Akad. Bd. xiv. no. 6, p. 22; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 12, 90; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii., Syst. p. 171; *id.* 1890, 'Morph. Skel. Steinkor.' Zeit. wiss. Zool. Bd. l. p. 301; Heilprin, 1890, 'Cor. W. Gulf Mex.' Proc. Acad. Nat. Sci. Phil. 1890, p. 307.

Madrepora mœandrites, var. γ, Pallas, 1766, 'Elench. Zooph.' p. 293.

Madrepora labyrinthiformis (pars), Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1274.

Distribution. Recent: West Indies, Bermuda, Florida. *Fossil*: Barbados: Low-level Reefs, near Bridgetown; High-level Reefs, Castle Grant, alt. 1070 feet (Jukes-Browne Coll.); Mt. Misery, 1053 feet (Col. Feilden Coll.); Orange Hill Plantation, St. Peter's (approx. 600 feet); Scotland, St. Andrews.

Genus Manicina, Ehrenberg, 1834.

Species Manicina areolata (Pallas), 1766.

Synonymy:—

Madrepora areolata, Linnæus, 1760, 'Syst. Nat.' ed. x. p. 795; Pallas, 1766, Elench. Zooph.' pp. 295–296.

Madrepora areolata (pars), Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 161, pl. xlvii. fig. 5, *non* fig. 4.

Madrepora areola, Esper, 1788, 'Pflanzenth.' Bd. i. pp. 84–87, pl. Madrep. v.

Mœandra areola, Oken, 1815, 'Lehrb. Naturg. Zool.' Abt. i. p. 70.

Mæandrina areolata, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 247; Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. pp. 283–284, pl. xvi. fig. 11; Lamouroux, 1821, 'Expos. Méth.' p. 55, pl. xlvii. figs. 4, 5; Blainville, 1823, 'Méandrine,' Dict. Sci. Nat. t. xxix. p. 376; Deslongchamps, 1824, 'Encycl. Méth., Zooph.' p. 508; Blainville, 1834, 'Man. Act.' p. 357; Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. p. 1095; Duchassaing, 1855, 'Form. mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. p. 756.

Manicina areolata, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 327; Leuckart, 1841, 'Zooph. Corall. speciatim Fungia,' p. 61, pl. iii. figs. 3, 4; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 191, pl. ix. fig. 3; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 286; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 91; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 397; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 350; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 48; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 176; Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., Quart. Journ. Geol. Soc. vol. xxiv. p. 16; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 72; Duncan, 1873, 'Old Tert. W. Ind.' Quart. Journ. Geol. Soc. vol. xxix. p. 555; Pourtalès, 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pls. v., vi. figs. 1–6; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 90–91; Wilson, 1888, 'Development, etc.' Journ. Morph. vol. ii. pp. 191–252, pls. i.–vii.; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii., Syst. p. 171; *non* A. Agassiz, 1890, 'Rate of Growth,' Bull. Mus. Comp. Zool. vol. xx. p. 62, pl. iii.

Madrepora mæandrites (pars), Esper, 1788, 'Pflanzenth.' pp. 76–84, pl. iv., not pl. iv. *a*.

Manicina mæandrites, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 193.

Manicina prærupta, Ehrenberg, 1834, 'Cor. roth. Meer.' p. 327.

Mæandrina pectinata (pars), Schweigger, 1820, 'Handb. Naturg.' p. 420.

Distribution. Recent: West Indies, Florida, Cape of Good Hope (*fide* Quelch), Indian Ocean and Australia (*fide* Ortmann). *Fossil*: Barbados: Low-level Reefs, near Bridgetown (Mitchinson Coll.); San Domingo, Nivajé Shale; St. Bartholomew (horizon ?); Guadeloupe (newer and older reefs).

Genus Mæandrina, Lamarck, 1801.

Species Mæandrina filograna (Esper).

Synonymy:—

Madrepora filograna, Esper, 1789, 'Pflanzenth.' Bd. i. pp. 139–140, pl. xxii. figs. 1, 2.

Mæandrina filograna, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 248; Blainville, 1823, 'Méandrine,' Dict. Sci. Nat. t. xxix. p. 377; Deslongchamps, 1824, 'Encycl. Méth., Zooph.' p. 509; Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 323; *id.* 1834, 'Man. Act.' p. 358; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 389; Michelin, 1842, 'Icon. Zooph.' p. 56, pl. xi. fig. 7; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 262; M.-Edwards & Haime, 1848, 'Classif. deux tribus Astr.' Compt. Rend. t. xxvii. p. 493; *iid.* 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. pp. 280–281; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 90; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. pp. 390–391; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 350; Duncan, 1863, 'West Ind. Cor.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 433; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 175; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 22.

Madrepora clivosa, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 163.

Mæandrina clivosa, Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 48; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 74; Lindström, 1877, 'Contrib. Act. Atl.' p. 22; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii., Syst. p. 170.

Mæandrina strigosa, Dana, 1848, *op. jam cit.* p. 257, pl. xiv. fig. 4; Verrill, 1864, *op. jam cit.* p. 49; Pourtalès, 1871, *op. jam cit.* p. 74; *id.* 1880, 'Florida Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pl. ix. figs. 6–9; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 92–94; Heilprin, 1890, 'Coral. W. Gulf Mex.' Proc. Acad. Nat. Sci. Phil. p. 306; *non* Bassett-Smith, 1890, 'Corals Tizard & Maccl. Bks.' Ann. Mag. Nat. Hist. ser. 6, vol. vi. p. 370.

Mæandrina sinuosissima, M.-Edwards & Haime, 1849, 'Monogr. Astr.' pt. 2, Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 281; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 393; Duncan, 1864, 'W. Ind. Cor.' pt. ii., Quart. Journ. Geol. Soc. vol. xx. p. 36; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 175; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29; Lindström, 1877, 'Contrib. Act. Atl.' p. 22; Quelch, 1886, 'Reef Corals,' pp. 91–92.

Mæandrina sinuosa (non Ellis), Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. pp. 278–281, pl. xv. figs. 4–7; Verrill, 1864, 'List of Corals,' p. 49.

? *Mæandrina dædalea*, Michelotti, 1838, 'Specim. Zooph.' p. 155, pl. v. fig. 5.

Mæandrina labyrinthica, Lesueur, 1820, *op. supra cit.* p. 282, pl. xvi. fig. 10; Ortmann, 1888, 'Staud. Verbr. Steinkor.' p. 170.

Mæandrina labyrinthiformis, Verrill, 1864, *op. supra cit.* p. 49; Ortmann, 1890, 'Morph. Skel. Steinkor.' Zeit. wiss. Zool. Bd. l. p. 301.

Distribution. Recent: West Indies, Florida, Bermuda. *Fossil*: Barbados: Low-level Reefs, Bridgetown; High-level Reefs, Welsh Town Gully (600 feet); San Domingo, Nivajé Shale.

Notes on Synonymy.—The synonymy of this species is very confusing, representatives of different genera having been included in the same species and many other species founded on mere individual variations. Quelch has considered the synonymy with care; he reduces many of M.-Edwards & Haime's species to synonyms, including *M. heterogyra*, *M. serrata*, *M. crassa*, and *M. labyrinthica*. The last of these, however, appears to me to be a *Cœloria*, while M.-Edwards & Haime include in *Cœloria* the *M. strigosa* of Dana, a step which does not seem to me justifiable. M.-Edwards & Haime's types are in the Paris Museum, but my notes on them having been lost, I do not care to express any positive opinion on the value of the series of species.

The species is restricted to the shores of the West Indies and the adjoining districts. It has been recently quoted from the Tizard Bank; the specimen on which the record is based is preserved in the British Museum. So far as I can determine it without a section, it appears to be a *Leptoria tenuis*, Dana.

Genus Mycetophyllia, M.-Edwards & Haime, 1848.

Species Mycetophyllia Lamarcki, M.-Edwards & Haime.

Synonymy:—

Mycetophyllia Lamarckana, M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. pl. viii. fig. 6; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat.' t. v. p. 80; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 376; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 350; *iid.* 1866, 'Suppl., etc.' *ibid.* ser. 2, t. xxiii. p. 173; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29.

Mycetophyllia Lamarcki, Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Distribution. Recent: West Indies. *Fossil*: Bermuda, Pleistocene (Coll. Geol. Soc.); Barbados: Low-level Reefs (Franks Coll.).

Subfamily Astræidæ confluentes.

Genus Colpophyllia, 1848, M.-Edwards & Haime.

Species Colpophyllia gyrosa (Ellis & Sol.), 1786.

Synonymy:—

Madrepora gyrosa, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 163, pl. li. fig. 2; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3763; Esper, 1795, 'Pflanzenth.' Fortsetz. pp. 100–101, pl. xxx.

Mæandrina gyrosa, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 247; Lamouroux, 1821, 'Exp. Méth.,' p. 55, pl. li. fig. 2; Blainville, 1823, 'Méandrine, Dict. Sci. Nat. t. xxix. p. 376; Deslongchamps, 1824, 'Encycl. Méth., Zooph.' p. 508; Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 323; *id.* 1834, 'Man. Act.' p. 357; Lamarck, 1836, 'Hist. Nat.' ed. 2, t. ii. p. 388; Schomburgk, 1847, 'Hist. Barbados, p. 562; Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. p. 1095; *id.* 1850, 'Anim. rad. Ant.' p. 16; *id.* 1855, 'Form. mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. pp. 754, 756.

Mussa gyrosa, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 186.

Manicina gyrosa, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 326.

Colpophyllia gyrosa, M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 266; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 84; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 384; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 349; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 49; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 174; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 74; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 22; Pourtalès, 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pl. ix. figs. 13–16; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12; Ortmann, 1890, 'Morph. Skel. Steinkor.' Zeit. wiss. Zool. Bd. l. p. 305.

Mussa fragilis, Dana, 1848, *op. supra cit.* p. 185, pl. viii. fig. 7.

Colpophyllia fragilis, M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xi. p. 267; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 84, p. 267; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 385; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 349; *iid.* 1866, 'Suppl. etc.' p. 174; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29.

Manicina mæandrites, non Esper, Ehrenberg, 1834, 'Cor. roth. Meer.' p. 326.

Colpophyllia tenuis, M.-Edwards & Haime, 1849, 'Monogr. Astr.' p. 267; *iid.* 1857, 'Hist. Nat. Cor.' p. 385; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 349; *iid.* 1866, 'Suppl. etc.' p. 174; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 29.

Distribution. *Recent*: West Indies, Bermuda. *Fossil*: Barbados: High-level Reefs, Castle Grant; Low-level Reefs, Bridgetown, Guadeloupe, Newer and older Reefs.

Notes on Synonymy.—The type of *C. tenuis* is in Paris, and seems to be only a young form of this species. The *C. fragilis* is probably a variation due to growth at a somewhat greater depth than the normal form. *C. breviserialis* appears to be definitely distinct.

Genus Hydnophora, Fischer de Waldheim.

Species Hydnophora latefundata, sp. n.

Diagnosis. Coral encrusting. Thin common plateau.

Monticules large, blunt, serial. Bases broad (whence specific name). High, conical or subcolumnar, often elongated transversely to the calicinal valleys. Irregularly distributed; usually in dichotomizing rows.

Septa thick, uniform; strongly dentate. Calicinal centres indistinct.

Dimensions. Height of monticules = 3 mm.; breadth = 3·4 mm.

Distribution. *Fossil*: Barbados: High-level Reefs, Castle Grant, 1070 feet (Jukes-Browne Coll.), Spring Estate, St. Andrews; Trinidad, St. Croix (Geol. Soc. Coll.).

Figures. Pl. XI. fig. 1 *a*. Specimen from Castle Grant (B. M. R.), nat. size. Pl. XI. fig. 1 *b*. Monticules enlarged.

Affinities. The genus *Hydnophora* has not been previously recorded

from the West Indies. Mr. R. Etheridge, Jun., has referred to it a fossil specimen now in the British Museum (Natural History), from Madeira. The only specimens from the West Indies, with the exception of those now received from Barbados, are some from Trinidad in the Museum of the Geological Society. One was identified by Duncan as *Agaricia agaricites* (Pall.) and the other as *Agaricia undata* (Ell. & Sol.); they were recorded as such in the 'Fossil Corals of the West Indies,' pt. iv.[1] They appear to be fairly typical representatives of this species.

H. latefundata is a very well-marked species. Its nearest ally is *H. exesa* (Ell. & Sol.)[2]—the *H. microconos* of Lamarck. This has been especially well figured by Klunzinger.[3] *H. exesa* differs, however, by growing in hemispherical masses; it has finer monticules, which are more crowded, so that the valleys are not so continuous. The calicinal centres are more distinct. *H. contignatio*, Forsk., which has also been well described by Klunzinger,[4] has not such regularly-arranged serial monticules, which in places almost unite into 'collines.' *H. tenella*, Quelch,[5] is another species that must be compared with the new one; *H. tenella* differs not only in its thin contorted sheets, but by having the calycinal centres more distinct; this species appears more Astræiform than any other in the genus.

Genus Dichocœnia, M.-Edwards & Haime, 1848.

Species Dichocœnia Stokesi, M.-Edwards & Haime.

Synonymy:—

Dichocœnia Stokesi, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 307, pl. vii. figs. 3, 3 *a*; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 200; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 341; *iid.* 1866, 'Suppl. etc.' *ibid.* p. 166; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 68; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 22.

Dichocœnia Cassiopœa, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 341; *iid.* 1866, 'Suppl. etc.' p. 166; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27.

Dichocœnia pulcherrima, Duchassaing & Michelotti, 1861, *op. cit.* pp. 341–342; *iid.* 1866, *op. cit.* p. 167; Duchassaing, 1870, *op. cit.* p. 27.

Dichocœnia æquinoxialis, Duchassaing & Michelotti, 1866, *op. cit.* p. 167; Duchassaing, 1870, *op. cit.* p. 27.

Dichocœnia elliptica, Duchassaing & Michelotti, 1866, *op. cit.* p. 167, pl. ix. figs. 11, 12; Duchassaing, 1870, *op. cit.* p. 27.

Dichocœnia pauciflora, Duchassaing & Michelotti, 1866, *op. cit.* p. 167, pl. ix. figs. 9, 10; Duchassaing, 1870, *op. cit.* p. 27; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Dichocœnia tuberosa, Duncan, 1863, 'W. Ind. Cor.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 432, pl. xv. figs. 5 *a*, 5 *b*.

Dichocœnia tuberosa, var., Duncan, 1864, do., pt. ii., *ibid.* vol. xx. p. 27; Duchassaing & Michelotti, 1866, *op. supra cit.* p. 168; Duchassaing, 1870, *op. supra cit.* p. 27.

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[1] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 12.

[2] 'Hist. Nat. Zooph.' p. 161, pl. xlix. fig. 3.

[3] 'Die Korallthiere des rothen Meeres,' pt. ii. Abt. ii. (1879) pp. 21–22, pl. iii. fig. 1, pl. ix. fig. 12 *d*.

[4] *Ibid.* pp. 22–23, pl. iii. figs. 2–3, pl. ix. figs. 12 *a–c*.

[5] 'Reef Corals collected by H.M.S. 'Challenger,'' Zool. 'Chall.' Exped. pt. xlvi. p. 96, pl. v. figs. 8–8 *a*.

Dichocœnia porcata (non auct.), Pourtalès, 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pl. x.

Barysmilia intermedia, Duncan, 1863, 'W. Ind. Cor.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 431, pl. xv. fig. 4; *id.* 1868, do. pt. iv., *ibid.* vol. xxiv. p. 23; Duchassaing & Michelotti, 1866, 'Suppl. etc.' p. 165; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27.

Distribution. Recent: West Indies. *Fossil*: Barbados: Low-level Reefs, near Bridgetown (Franks Coll.); San Domingo: Esperanza Shale, Nivajé Shale, and Tufaceous Limestone.

Notes on Synonymy.—This species has given rise to great difficulty; its earliest history I have not been able to unravel. It was confused with *Dichocœnia uva* (Esper), and many of the early records of this East Indian species are no doubt based on *D. Stokesi*. Duchassaing & Michelotti had a fine series of specimens, all now in the Museum at Turin; their new species seem to be based on individual variations. *D. pauciflora* is a form with scattered calices. *D. elliptica* is a form that has grown quickly, so that the calices are crowded, and they have undergone repeated fission. *D. æquinoxialis* is a variety also with crowded calices; these average 6 mm. in length by 3 mm. in breadth, and are separated by cœnenchyma only 1 mm. broad; it appears, however, to have grown slowly, as fission is much rarer than in the previous form. *D. guadalupensis* is a small undergrown variety of *æquinoxialis*. The *D. porcata* of Pourtalès is a variety in which the formation of long series of confluent calices has reached its extreme limit for this species. Duncan's *Barysmilia intermedia* appears to be a young form of this; it looks much like a *Barysmilia* externally, but, as the specimen has a well-marked columella, it cannot belong to that genus.

The two species *D. uva* and *D. Stokesi* are closely allied. The distinctions that separate them from *D. porcata* are so well marked as to be probably of subgeneric value.

Genus Lamellastræa, Duncan, 1868.

Species Lamellastræa Smythi, Duncan.

Synonymy:—

Lamellastræa Smythi, Duncan, 1868, 'W. Ind. Foss. Cor.' Quart. Journ. Geol. Soc. vol. xxiv. p. 20, pl. i. figs. 2 *a*, 2 *b*.

Distribution. Fossil: Antigua Marl (type Brit. Mus.); Barbados: High-level Reefs, Castle Grant (Jukes-Browne Coll.).

Genus Favia, Oken, 1815.

Species Favia ananas (Pallas), 1766.

Synonymy:—

Madrepora ananas, Pallas, 1766, 'Elench. Zooph.' p. 321; Ellis & Solander, 1786, 'Hist. Nat. Zooph.' p. 168, pl. xlvii. fig. 6; *non* Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1275; *non* Esper, 1789, 'Pflanzenth.' pp. 128–131, pl. Madrep. xix.

Favia ananas (pars), Oken, 1815, 'Lehrb. Naturg. Zool.' Abth. i. p. 67.

Favia ananas, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 435; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 352; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 48; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 177; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 75.

Astræa ananas (pars), Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 260.

Astræa ananas, Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. p. 285, pl. xvi. fig. 12; Schweigger, 1820, 'Handb. Naturg.' p. 419.

Astræa ananas (pars), Lamouroux, 1821, 'Expos. Méth.' p. 59, pl. xlvii. fig. 6; *id.* 1824, 'Encycl. Zooph.' p. 127.

Non *Astræa ananas*, Eichwald, 1829, 'Zool. Spec.' pars i. p. 183.

Astræa ananas (pars), Blainville, 1834, 'Man. Act.' p. 369.

Non *Astræa ananas*, Quoy & Gaimard, 1834, 'Voy. Astrolabe,' Zool. t. iv. p. 207, pl. xvi. figs. 6, 7.

Astræa ananas, pars, Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 406.

Astræa ananas, Schomburgk, 1874, 'Hist. Barbados,' p. 562; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 222; Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. p. 1095; *id.* 1850, 'Anim. rad. Ant.' p. 16; *id.* 1855, 'Form. mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. pp. 754, 756; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 12, 98.

Explanaria ananas, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 307.

Parastræa ananas, M.-Edwards & Haime, 1850, Ann. Sci. Nat. Zool. sér. 3, t. xii. p. 172.

Distribution. Recent: West Indies, Florida, Bermuda. *Fossil*: Barbados: Low-level Reefs, near Bridgetown (Mitchinson Coll.); Guadeloupe, newer and older reefs.

Notes on Synonymy.—The great confusion with this species is due to Linnæus and Esper, who applied the name to an East-Indian coral, which is no doubt *Dichocœnia porcata*. Schweigger, in 1820, clearly recognized this; but many later authors have continued to use the name either for the East Indian species only or for both. The collection at the Museum of Comparative Zoology at Harvard contains some typical specimens from Barbados which agree exactly with one from the raised reefs.

Subfamily Astræidæ gemmantes.

Genus Orbicella, Dana, 1848.

Species 1. Orbicella radiata (Ellis & Solander), 1786.

Synonymy:—

Madrepora radiata, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 169, pl. xlvii. fig. 8; 'Gmelin,' 1790, Syst. Nat. ed. xiii. p. 3765; Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. pp. 74–75, Madrep. pl. lxi.

Astræa radiata, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 258; Lamouroux, 1821, 'Expos. Méth.' p. 57, pl. xlvii. fig. 8; *id.* 1824, 'Encycl. Méth., Zooph.' p. 132; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 404; Schomburgk, 1847, 'Hist. Barbados,' p. 562; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xii. p. 101.

Astræa radiata, var. *intermedia*, Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 421.

Astræa (*Tubastræa*) *radiata*, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 334, pl. xxxv. fig. 8; *id.* 1834, 'Man. Act.' p. 368, pl. lv. fig. 8.

Explanaria radiata, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 307.

Orbicella radiata, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 206.

Heliastræa radiata, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 470; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 352; *iid.* 1866, 'Suppl. etc.' *ibid.* ser. 2, t. xxiii. p. 179; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Madrepora cavernosa, Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1276; Gmelin, 1790, *op. cit.* ed. xiii. p. 3767; Esper, 1794, 'Pflanzenth.' Fortsetz. Bd. i. pp. 18–21, pl. Madrep. xxxvii.

Non *Madrepora cavernosa*, Schlotheim, 1820, 'Petrefactenkunde,' p. 358.

Favia cavernosa seu *astroïtes*, Oken, 1815, 'Lehrb. Naturg. Zool.' Abt. i. p. 67.

Astræa cavernosa, Schweigger, 1820, 'Handb. Naturg.' p. 419; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. pl. ix. fig. 1, t. xii. p. 97; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 97.

Non *Astræa cavernosa*, Quenstedt, 1852, 'Handb. Petref.' p. 647, pl. lvii. fig. 22; *id.* 1883, *op. cit.* ed. iii. p. 1000, pl. lxxx. fig. 11; Faurot, 1888, 'Miss. Mer Rouge,' Arch. Zool. Expér. sér. 2, t. vi. p. 119.

Astræa (*Tubastræa*) *cavernosa*, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 334; *id.* 1834, 'Man. Act.' p. 368.

Heliastræa cavernosa, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 463.

Heliastræa cavernosa, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 352; *iid.* 1866, 'Suppl. etc.' p. 179; Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., Quart. Journ. Geol. Soc. vol. xxiv. p. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Orbicella cavernosa, Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 47; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 76; Lindström, 1877, 'Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 23; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 12, 106; Heilprin, 1890, 'Cor. W. Gulf Mex.' Proc. Acad. Nat. Sci. Phil. 1890, p. 306.

Astræa Argus, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 259; Lamouroux, 1824, Encycl. Méth., 'Zooph.' p. 131; Eichwald, 1829, 'Zool. Spec.' t. i. p. 183; Schomburgk, 1847, 'Hist. Barbados,' p. 562; Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. pp. 1095, 1097; M.-Edwards & Haime, 1848, 'Classif. deux. tribu Astr.' Compt. Rend. t. xxvii. p. 494; Duchassaing, 1850, 'Anim. rad. Ant.' p. 15; *id.* 1855, 'Form. mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. pp. 754, 756.

Orbicella Argus, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 207, pl. x. fig. 1, p. 75, fig. 34.

Explanaria Argus, Ehrenberg, 1834, 'Cor. roth. Meer.' p. 307.

Astræa endothecata, Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 434, pl. xv. fig. 7.

Heliastræa endothecata, *id.* 1868, *op. cit.* pt. iv., *ibid.* vol. xxiv. p. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Astræa cylindrica, Duncan, 1863, *op. supra cit.* vol. xix. p. 434, pl. xv. fig. 8.

Heliastræa cylindrica, *id.* 1868, *op. cit.* vol. xxiv. p. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Heliastræa aperta, Verrill, 1868, 'Notes on Radiata,' Trans. Conn. Acad. vol. i. pt. 2, p. 356.

Distribution. Recent: West Indies, Florida, Vera Cruz, Brazil. *Fossil*: Barbados: Low-level Reefs near Bridgetown (Franks Coll.); Ceres (Jukes-Browne Coll.); High-level Reefs, Spring Estate, St. Andrews; Bissex Hill, near foot of crest; Gully by Farmer's Shaft No. 3; Welsh Town Gully (600 feet); Mt. Hillaby (780 feet). Trinidad, St. Croix; Antigua, Marl; Guadeloupe, newer and older reefs; San Domingo, Tufaceous Limestone, Nivajé Shale; Bermuda, raised reefs (Coll. Geol. Soc.)

Notes on the Species.—The group of Astræan corals of the alliance *Orbicelloida* is the most difficult in the West Indian fauna. The first species, however, is fairly well marked. I have adopted for it the name *radiata*, though *cavernosa* is earlier. But Linnæus's diagnosis of this is so imperfect and inadequate that it is absolutely useless. Ellis and Solander, on the other hand, gave a figure; this, unfortunately, was based on a worn broken specimen, but is nevertheless clearly recognizable. It appears, however, at first so different from Esper's admirable figure of *M. cavernosa* that the two species were regarded as distinct.

The *O. aperta* of Verrill seems to me to be only a specimen of this species, in which the fourth cycle of septa is incomplete. It looks somewhat different, as the cœnenchyma is more cellular and the septa are thinner; in all fundamental points it agrees with *O. radiata*. The specimen probably grew under less favourable conditions than those of the West Indian seas, and thus is less massive. Verrill's type is preserved in the Museum of Yale College, to the authorities of which I am indebted for the opportunity of studying it.

Species 2. Orbicella acropora (Linnæus), 1767.

Synonymy :—

Madrepora acropora, Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1276; Gmelin, 1790. *ibid.* ed. xiii. p. 3767; Esper, 1794, 'Pflanzenth.' Fortsetz. Bd. i. pp. 21–23, pl. Madrep. xxxviii.

Heliastræa acropora, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 477; Duchassaing & Michelotti, 1861, 'Mem. Cor. Ant.' Mém. R. Accad. Sci. Torino, ser. 2, t. xix. p. 179; *iid.* 1866, 'Suppl. etc.' *ibid.* ser. 2, t. xxiii. p. 352; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Madrepora annularis, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 169, pl. liii. figs. 1–2.

Astræa annularis, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 259; *id.* 1816, 'Encycl. Méth. Atlas,' pl. 486. figs. 1–2; Lamouroux, 1821, 'Expos. Méth.' p. 58, pl. liii. figs. 1–2; *id.* 1824, Encycl. Méth., 'Zooph.' p. 131; Lamarck, 1836, 'Hist. Nat.' ed. 2, t. ii. p. 405; Schomburgk, 1847, 'Hist. Barbados,' p. 562; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xii. p. 104

Astræa (*Tubastræa*) *annularis*, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 334; *id.* 1834, 'Man. Act.' p. 368.

Explanaria annularis, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 308.

Orbicella annularis, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 214, pl. x. fig. 6; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 48; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 77; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 23; Pourtalès, 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pl. iv; A. Agassiz, 1890, 'Rate of Growth,' Bull. Mus. Comp. Zool. vol. xx. p. 61, pls. i., ii.; Heilprin, 1890, 'Cor. W. Gulf Mexico,' Proc. Acad. Nat. Sci. Phil. 1890, p. 305.

Heliastræa annularis, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 473; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 352; *iid.* 1866, 'Suppl. etc.' p. 179; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30; Ortmann, 1888, 'Stud. Syst. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 174; *id.* 1889, 'Steinkor. Ceylons,' *ibid.* Bd. iv. Syst. p. 529; *id.* 1890, 'Morph. Skel. Steinkor.' Zeitschr. Wiss. Zool. Bd. l. p. 307.

Madrepora faveolata, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 166, pl. liii. figs. 5–6; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3769.

Orbicella Hyades, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 212, pl. x. fig. 15.

Heliastræa? Hyades, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 478.

Solenastræa Hyades, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 353; *iid.* 1866, 'Suppl. etc.' p. 179; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Heliastræa abdita, Duchassaing & Michelotti, 1861, *op. supra cit.* p. 352; *iid.* 1866, *op. supra cit.* p. 179; Duchassaing, 1870, *op. supra cit.* p. 30.

Heliastræa rotulosa, Duchassaing & Michelotti, 1861, *op. supra cit.* p. 352; *iid.* 1866, *op. supra cit.* p. 179; Duchassaing, 1870, *op. supra cit.* p. 30.

Astræa barbadensis, Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. pp. 421, 444–445, pl. xv. fig. 6 *a*, *b*.

Heliastræa barbadensis, Duchassaing & Michelotti, 1866, 'Mém. Cor. Ant.' p. 180; Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., Quart. Journ. Geol. Soc. vol. xxiv. p. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

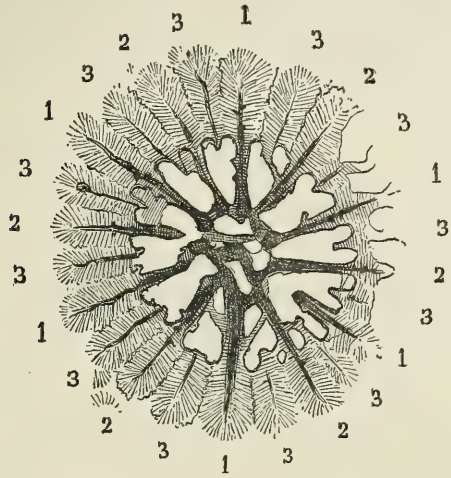
Heliastræa altissima, Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., vol. xxiv. pp. 12–13, pl. ii. fig. 3.

Distribution. Recent: West Indies, Florida, Yucatan, ? Samoa (*fide* Ortmann). *Fossil*: Barbados: Low-level Reefs near Bridgetown (Franks Coll.); Ceres (Jukes-Browne Coll.); High-level Reefs, Castle Grant, 1050 feet (Jukes-Browne Coll.); summit of Mt. Misery, 1053 feet (Col. Feilden Coll.). Trinidad, St. Croix (Geol. Soc. Coll.); Antigua, Marl.

Notes on Synonymy.—The main point in the synonymy of this species is the determination as to whether *O. annularis* should be kept distinct. At first I thought that this could be done, owing to the fact that in *O. annularis* the costæ are subequal, though the septa of the third cycle are very small. In *O. acropora*, on the other hand, there is a rudimentary costa between those corresponding to the third cycle of septa; these rudimentary costæ do not themselves correspond to septa. This point seemed a satis-

factory means of establishing the distinctness of the two species, until an additional section showed that in some corallites one half is on the *acropora*-type and the other on that of *annularis*.

Fig. 2.—*Section of* Orbicella acropora (*Linn.*). ×10 *diam.*



Genus Solenastræa, M.-Edwards & Haime.

Species Solenastræa stellulata (Ellis & Solander), 1786.

Synonymy:—

Madrepora stellulata, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 165, pl. liii. figs. 3–4; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3767.

Astræa stellulata, Lamouroux, 1821, 'Expos. Méth.' p. 58, pl. liii. figs. 3–4; *id.* 1824, Encycl. Méth., 'Zooph.' p. 131, pl. 484. figs. 3–4; Blainville, 1830, Dict. Sci. Nat. t. lx. p. 334; M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xii. p. 105.

Orbicella stellulata, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 215, pl. x. fig. 7.

Heliastræa stellulata, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 473; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Torino, ser. 2, t. xix. p. 352; *iid.* 1866, 'Suppl. etc.' *ibid.* ser. 2, t. xxiii. p. 179; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Solenastræa Verheltsi (non M.-Ed. & H.), Duncan, 1864, 'Foss. Cor. W. Ind.' pt. ii., Quart. Journ. Geol. Soc. vol. xx. p. 40.

Solenastræa Verheltsi, Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

? *Solenastræa Bournoni*, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 497.

Distribution. Recent: West Indies. *Fossil*: Barbados: High-level Reefs, Castle Grant, 1070 feet (Jukes-Browne Coll.). San Domingo, Tufaceous Limestone; Jamaica (Coll. Geol. Soc.).

Notes on the Species.—Duncan referred to the Eocene species, *S. Verheltsi*, a worn fragment from San Domingo preserved in the Museum of the Geological Society. I have been allowed to have a microscopic preparation cut from this, which shows a well-marked columella. It cannot therefore be included in the French species.

Some of the specimens collected by Mr. Jukes-Browne at Castle Grant are extremely well preserved. Others, however, are much worn; the septa in these having been removed, the corals look like *Cyphastræa*, in which genus I was at first inclined to include them. More careful study of vertical sections shows that the septa are not cribriform, though very brittle. The corallites present two different aspects: in one the thecal wall and costæ are thin; in another group from the same slab both these elements are coarse and thick. Pl. XI. figs. 4 *a*, 4 *b*, show the very different appearance which these present.

Genus Cyphastræa, M.-Edwards & Haime, 1848.

Species Cyphastræa costata, Duncan.

Synonymy:—

Cyphastræa costata, Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. pp. 436, 441, 443; *id.* 1865, 'Foss. Cor. Jam.' *ibid.* vol. xxi. p. 7; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 180: Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 30.

Cyphastræa oblita, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 353; *iid.* 1866, 'Suppl. etc.' p. 180; Duchassaing. 1870, 'Rev. Zooph. Ant.' p. 30; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Distribution. *Recent*: St. Thomas, West Indies. *Fossil*: Barbados: High-level Reefs; Castle Grant, 1070 feet; Groves, 650 feet; Low-level Reefs, near Bridgetown. San Domingo, Nivajé Shale; Jamaica; Barbuda.

Notes on Synonymy.—This species has been well described by Duncan from a specimen from Barbuda. It was named by Duchassaing & Michelotti two years previously; but they gave so inadequate a diagnosis that their name has no claim to precedence. The coral looks at first sight much like *Orbicella acropora* (L.), from which it may be distinguished at once by its thicker thecal walls and more cellular exotheca. The whole aspect of the coral is coarser and looser. The cribriform nature of the septa is extremely well marked. Following Duncan, but differing from Klunzinger and Quelch, I prefer to keep *Cyphastræa* and *Solenastræa* distinct.

Genus Echinopora, Lamarck, 1816.

Species Echinopora Franksi, sp. n.

Diagnosis. The coral has a broad base; from this pass outward short, thick, rapidly tapering expansions.

Corallites long: often an inch in length. Their distance one from the other varies from half their diameter to the whole.

Septa strongly dentate; inner teeth paliform, in three cycles. Those of the first cycle always unite to the columella; those of the second cycle often do so, but may join the primary septa; those of the third cycle are much smaller and independent, but a few may unite with the septa of the other orders.

Columella of very loose tissue; half the diameter of the corallite.

Endotheca scanty. Cœnenchyma thinner than in other species of the genus. Echinulation of the surface coarse. Epitheca thick and well developed.

Dimensions. Diameter of an average corallite, 3 mm.; height of corallite varies from 10 to 25 mm.; thickness of wall varies from $1\frac{1}{2}$ to 3 mm.

Distribution. Recent: West Indies. *Fossil*: Barbados: Low-level Reefs, near Bridgetown (Franks Coll.).

Figures. Pl. XI. fig. 2 *a*, the coral reduced to $\frac{1}{3}$; fig. 2 *b*, corallites from the surface of a flat area; fig. 2*c*, corallites on a boss on the same specimen (B.M. R 2514); fig. 3, section of a corallite, enlarged from another specimen (B.M. R 2513).

Affinities. This species is most closely allied to *Echinopora rosularia*, Lamk., of which a good figure has been given by Blainville ('Man. Act.' pl. lvi. fig. 2). The old species may, however, be easily distinguished by the greater irregularity in the distribution of the corallites, which are much farther apart. *E. aspera* (Ell. & Sol.) agrees in the general form, but differs by the great development of spines and denticles on the upper surface; the thinness of the branches, and the rudimentary character of the epitheca, also separate the species. *E. Ehrenbergi*, M.-Ed. & H.,[1] sometimes approaches *E. Franksi* in the thickness of the expanding lobes, but these never attain the strength of the West Indian species; the cœnenchyma in the latter is, moreover, radially echinulate and not irregularly spinous.

This species is, in fact, exceptionally well marked off from those species of which adequate illustrations and descriptions have been given. The genus, moreover, has not been previously definitely recorded from the West Indies. Lamarck[2] described a species, *E. ringens*, of which he says 'je la crois des mers d'Amérique.' Dana ('Zoophytes,' p. 279) has quoted Lamarck's diagnosis, and puts it as 'West Indies?' Two points in this scanty diagnosis suggested at first that the Barbados specimens really belong to this species: these are the general form of the coral and the closeness of the corallites. The former character is, however, of little value; and doubt is thrown on the last by the corallites being also described as subconfluent and sinuous. In this species they certainly are not, and this is really the only definite character in Lamarck's diagnosis. The corallites, moreover, instead of being irregular, are more regular than in most species of the genus. It would therefore be unwise to resuscitate Lamarck's practically unrecognized name. I have much pleasure in naming the species after Mr. G. F. Franks, by whose energy in forming a collection of recent and fossil species from Barbados it has been possible to work out the relations of the two faunas.

[1] Ann. Sci. Nat. Zool. sér. 3, t. xii. (1850) p. 187.
[2] 'Hist. Nat.' 1816, vol. ii. p. 256.

Genus Stephanocœnia, M.-Edwards & Haime, 1848.

Species Stephanocœnia intersepta (Esper), 1797.

Synonymy :—

Madrepora intersepta, Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. p. 99, pl. Madrep. lxxix.

Astræa intersepta, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 266; Lamouroux, 1824, Encycl. Méth., 'Zooph.' p. 127; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 417.

Non *Astræa intersepta*, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 246.

Astræa intersepta, Duchassaing, 1850, 'Anim. rad. Ant.' p. 16.

Astræa (*Cellastræa*) *intersepta*, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 342; *id.* 1834, 'Man. Act.' p. 377.

Stephanocœnia intersepta, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 300, pl. vii. figs. 1–1 *b*; *id.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 66; *id.* 1857, 'Hist. Nat. Cor.' t. ii. p. 265; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 343.

Stephanocœnia intersepta, var., Duncan, 1864, 'Foss. Cor. West Ind.' pt. ii., Quart. Journ. Geol. Soc. vol. xx. p. 27.

Stephanocœnia intersepta, Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 168; Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., Quart. Journ. Geol. Soc. vol. xxiv. p. 12; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Stephanocœnia Michelini, M.-Edwards & Haime, 1848, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. x. p. 301; *iid.* 1857, 'Hist. Nat. Cor.' t. ii. p. 266; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 343; *iid.* 1866, 'Suppl. etc.' p. 169; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 27; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Plesiastræa spongiformis, Duncan, 1864, 'Foss. Cor. W. Ind.' pt. ii., Quart. Journ. Geol. Soc. vol. xx. p. 39, pl. iv. fig. 6, *a*, *b*.

Antillastræa spongiformis, Duncan, 1884, 'Revis. Madr.' Journ. Linn. Soc., Zool. vol. xviii. p. 108.

Distribution. *Recent*: West Indies. *Fossil*: Barbados: Low-level Reefs, Ceres, and near Bridgetown; Guadeloupe, White Limestone (*fide* Duchassaing); Trinidad, St. Croix; San Domingo, silt.

Notes on Synonymy.—This species has three different varieties, all of which may occur on the same block. In the typical form, as shown in M.-Edwards & Haime's figure (Ann. Sci. Nat. sér. 3, vol. x. pl. vii. fig. 1) and some of the specimens from the Barbados reefs (for example, B.M. R 2533), the calices are polygonal and crowded, and separated by thin raised ridges. An extreme type of this is shown in Pl. XI. fig. 5 *a*, taken from a specimen from the Low-level Reefs (B.M. R 2533). On another portion of this specimen the calices are separated by low flat areas formed by the separation of the thecal walls (see Pl. XI. fig. 5 *b*). The third type appears very different. The corallites are circular, and are separated from one another by depressed bands; the septa, moreover, are exsert. This type is shown in Pl. XI. fig. 6; this is the variety described by M.-Edwards & Haime as *S. Michelini*. The instructive series of specimens sent from Barbados by Messrs. G. F. Franks and A. J. Jukes-Browne clearly show that all these are phases of the same species.

Duncan has described two species from Antigua (*S. Reussi* and *S. tenuis*) which are quite distinct.

The inclusion of the species made by Duncan in the type of a new genus, *Antillastræa*, necessitates the consideration of the four species originally placed by Duncan in *Plesiastræa*. The types are all in the Museum of the Geological Society; I have been kindly permitted to have sections prepared from these. Without such sections I could not have come to any conclusion as to the affinities

of the species. In his 'Revision' Duncan seems to have been puzzled by this group of species, and left three of them in *Plesiastræa*, apparently with considerable hesitation. For the fourth he proposed the genus *Antillastræa*. I can see no difference whatever between this and *Stephanocœnia*, and feel no doubt that had Prof. Duncan compared the two he would have recognized their identity; but, as he placed them in different alliances, he probably did not compare them.

Plesiastræa globosa, Duncan, is a *Leptastræa*, and is probably *L. caribœa*, Duch. & Mich.; *P. ramea*, Duncan, appears to me to be an *Orbicella*, as the structures regarded by Duncan as pali are probably only paliform lobes.

Family PLESIOFUNGIDÆ.

Genus Astræa, Lamarck, 1801.

Species 1. Astræa radians (Pallas), 1766.

Synonymy:—

Madrepora radians, Pallas, 1766, 'Elench. Zooph.' pp. 322–323.

Astræa radians, Fischer de Waldheim, 1807, 'Mus. Demid.' t. iii. p. 295; Oken, 1815, 'Lehrb. Naturg.' Zool. Bd. i. p. 65; M.-Edwards & Haime, 1857, 'Hist. Nat. Cor. t. ii. pp. 506–507; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Nat. Torino, ser. 2, t. xix. p. 354; *iid.* 1866, 'Suppl. etc.' *ibid.* ser. 2, t. xxiii. p. 182; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Siderastræa radians, Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 55; Lindström, 1877, 'Contr. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 23; Ortmann, 1888, 'Syst. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 181; *id.* 1890, 'Morph. Skel. Steinkor.' Zeitschr. wiss. Zool. Bd. l. p. 298.

Madrepora astroïtes, Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1276; Gmelin, 1790, *ibid.* ed. xiii. p. 3767; Esper, 1794, 'Pflanzenth.' Forsetz. Bd. i. pp. 12–16, pl. Madrep. xxxv.

Astræa astroïtes, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 319.

Madrepora galaxea, Ellis & Solander, 1786, 'Hist. Nat. Zooph.' p. 168, pl. xlvii. fig. 7; Gmelin, 1790, *op. cit.* p. 3765.

Astræa galaxea, Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 371; *id.* 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 267; Lesueur, 1820, 'Polyp. Lamell.' Mém. Mus. Hist. Nat. t. vi. p. 285, pl. xvi. fig. 13; Lamouroux, 1821, 'Expos. Méth.' p. 60, pl. xlvii. fig. 7; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 418; Duchassaing, 1850, 'Anim. rad. Ant.' p. 15; *id.* 1855, 'Form. mod. Guad.' Bull. Soc. géol. France, sér. 2, t. xii. p. 754.

Siderastræa galaxea, Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 335; *id.* 1834, 'Man. Act.' p. 370; M.-Edwards & Haime, 1848, 'Classif. deux tribu Astr.' Compt. Rend. t. xxvii. p. 495; *iid.* 1849, 'Monogr. Astr.' Ann. Sci. Nat. Zool. sér. 3, t. xii. p. 139; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 105; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 81; *id.* 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. no. 1, pl. xi. figs. 14–21, pl. xv. figs. 1–12; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 12, 113; Heilprin, 1890, 'Cor. W. Gulf Mex.' Proc. Ac. Nat. Sci. Phil. 1890, p. 305.

Explanaria galaxea, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832 p. 306.

Siderina galaxea, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 218, pl. x. figs. 12, 12 *b*, *c* (*non* figs. 12 *a*, *d*).

? *Astræa punctifera*, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 260; Lamouroux, 1824, Encycl. Méth., 'Zooph.' p. 132; Lamarck, 1836, 'Hist. etc.' ed. 2, t. ii. p. 407.

Astræopora punctifera, Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 349; *id.* 1834, 'Man. Act.' p. 383.

Distribution. Recent: West Indies, Florida, Vera Cruz. *Fossil*: Barbados, Low-level Reefs; Bahamas, Pleistocene Reefs (Coll. Geol. Soc.).

Notes on Synonymy.—As this is the type-species of its genus, it is convenient to consider in connexion with it the correct name of the genus—a subject which has given rise to much difference of opinion. Lamarck, in 1801, used the term *Astræa* for two species, *rotulosa* and *galaxea*, but does not definitely name either as the type. Fischer de Waldheim came next; he quoted Lamarck's diagnosis, with only unimportant verbal additions. He does not mention *rotulosa*, but includes *radians* in *Astræa*. The diagnosis used both by him and Lamarck certainly applies better to *radians* than to *rotulosa*.

The genus was first properly subdivided by Oken in 1817. He restricted *Astræa* to *galaxea*, and proposed the genus *Favia* for the other. According to the rule—that when an author includes two or more species in a genus which is subsequently dismembered, and does not definitely choose one species as his type, the author who subdivides the genus has the right to select any species as the type—M.-Edwards & Haime were quite right in taking *radians* as the type of *Astræa*. This leads, however, to the unfortunate position that *Astræa* is not one of the Astræan corals. To obviate this difficulty, Blainville renamed *Astræa*, *Siderastræa*. Duncan follows the same course, by which *Astræa* would fall out of use. Quelch, however, goes back beyond Oken, uses *Astræa* for the *rotulosa*-group of species, makes *Favia* a synonym of *Astræa*, and accepts *Siderastræa* for the *radians*-group.

But this course is opposed to the rule already quoted. The only chance of escape from the solution adopted by M.-Edwards & Haime is a prior use of the name *Astræa*. Before Lamarck, Gmelin used it for *Madrepora astroïtes* (p. 3767), but his diagnosis is so uncertain that one cannot base anything upon it. Brown [1] used *Astræa* for a coral, but his description is so ill-defined that it is impossible to recognize what was intended. Bolten used the term for a mollusc in 1798; but it is not used in conchology, and I cannot find what he meant by it. We seem, therefore, bound to follow the course taken by Milne-Edwards & Haime.

Species 2. Astræa siderea (Ell. & Sol.), 1786.

Synonymy:—

Madrepora siderea, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 168, pl. xlix. fig. 2; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3765.

Astræa siderea, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 267; Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. p. 286, pl. xvi. fig. 14; Lamouroux, 1821, 'Exp. Méth.' p. 60, pl. xlix. fig. 2; *id.* 1824, Encycl. Méth., 'Zooph.' p. 126; Lamarck, 1836, 'Hist. Nat. etc.' ed. 2, t. ii. p. 417; M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 509; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 354; *iid.* 1866, 'Suppl. etc.' *ibid.* sér. 2, t. xxiii. p. 183; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Astræa (*Siderastræa*) *siderea*, Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 335; *id.* 1834, 'Man. Act.' p. 370.

Siderastræa siderea, M.-Edwards & Haime, 1849, 'Monogr. Astr.' Ann. Sci. Nat., Zool. sér. 3, t. xii. p. 141; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 105; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 55; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 81.

[1] Patrick Brown, 'Civil & Natural History of Jamaica,' 1789, p. 392.

Pavonia siderea, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 331.
Astræa trichophylla, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 319.
? *Siderastræa globosa*, M.-Edwards & Haime, 1849, 'Monogr. Astr.' p. 141.
? *Astræa globosa*, M.-Edwards & Haime, 1857, 'Hist. Nat. Cor.' t. ii. p. 510.
Siderastræa grandis, Duncan, 1863,' Wt. Ind. Cor.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 441, pl. xvi. fig. 5; *id.* 1864, *op. cit.* pt. ii., *ibid.* vol. xx. p. 40.
Astræa grandis, Duncan, 1868, *op. cit.* pt. iv., *ibid.* vol. xxiv. pp. 18, 20; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.
Siderastræa crenulata, Blv., var. *Antillarum*, Duncan, 1863, *op. cit.*, Quart. Journ. Geol. Soc. vol. xix. p. 435; *id.* 1865, 'Cor. Jam.' *ibid.* vol. xxi. p. 11.
Astræa crenulata (*non* Blainv.), Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.
Siderastræa stellata, Verrill, 1868, 'Notes on Radiata,' pt. iv., Trans. Connect. Acad. vol. i. p. 352.

Distribution. *Recent*: West Indies; Florida; Abrolhos Banks, Brazil. *Fossil*: Barbados: Low-level Reefs, Ceres (Jukes-Browne Coll.), near Bridgetown (Franks Coll.); High-level Reefs, Castle Grant, 1070 feet (Jukes-Browne Coll.); Spring Estate, St. Andrews; Two Mile Hill, St. Michael's. San Domingo, Nivajé Shale; Jamaica.

Notes on Synonymy.—The only point requiring notice in the synonymy of this species is in reference to Duncan's species *A. grandis* and his identification of some specimens as a variety of the common Italian Miocene form, *A. crenulata* (Blv.). Duncan's type of the former is preserved in the British Museum; sections of it agree exactly with those of *A. siderea* from Barbados. The specimen on which he based his record of *A. crenulata* is a small one, and appears to be only a young form of this species.

Family LOPHOSERIDÆ.

Genus Agaricia, Lamarck, 1801.

Species 1. Agaricia agaricites (Pallas), 1766.

Synonymy:—
Madrepora agaricites, Pallas, 1766, 'Elench. Zooph.' pp. 287–289; Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1274; Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 159, pl. lxiii.; Esper, 1789, 'Pflanzenth.' Bd. i. pp. 132–135, pl. Madr. xx.; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3759.
Undaria agaricites, Oken, 1815, 'Lehrb. Naturg. Zool.' Bd. i. p. 69.
Pavonia agaricites, Lamarck, 1816, 'Hist. Anim. s. Vert.' t. ii. p. 239; Lamouroux, 1821, 'Exp. Méth.' p. 53, pl. lxiii.; Deslongchamps, 1824, Encycl. Méth., 'Zooph.' p. 604; Blainville, 1825, *Pavonia*, Dict. Sci. Nat. t. xxxviii. p. 167; Eichwald, 1829, 'Zool. Spec.' pars i. p. 185; Blainville, 1830, 'Zoophyte,' Dict. Sci. Nat. t. lx. p. 330; *id.* 1834, 'Man. Act.' p. 365.
Mycedia agaricites, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 342.
Agaricia agaricites, M.-Edwards & Haime, 1851, 'Monogr. Fong.' Ann. Sci. Nat. Zool. sér. 3, t. xv. p. 127; *id.* 1860, 'Hist. Nat. Cor.' t. iii. p. 81; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 356; Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 437; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 55; *id.* 1868, 'Notes on Rad.' iv., Trans. Conn. Acad. vol. i. p. 352.
Non *Agaricia agaricites*, Duncan, 1868, 'Foss. Cor. W. Ind.' pt. iv., Quart. Journ. Geol. Soc. vol. xxiv. p. 12.
Agaricia agaricites, Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 82; Lindström, 1877, 'Contrib. Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 23; Pourtalès, 1880, 'Flor. Rfs.' Mem. Mus. Comp. Zool. vol. vii. no. i. pl. xi. figs. 11–13, pl. xii. figs. 1–3; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 12, 117; Ortmann, 1888, 'Syst. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 181.
Pavona cristata, Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 372.
Pavonia cristata, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 328.

Non *Pavonia cristata*, Lamarck, 1816, *et auct.*; ? Deslongchamps, 1824, Encycl. Méth. p. 604.

Agaricia cristata, Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. p. 1097.

? Agaricia arthrophylla, Horn, 1860, Proc. Acad. Nat. Sci. Phil. 1860, p. 435.

Madrepora undata, Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 157, pl. xl.; Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. p. 98, pl. Madr. lxxviii.

Agaricia undata, Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 373; *id.* 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 242; Lamouroux, 1821, 'Exp. Méth.' p. 54, pl. xl.; *id.* 1824, Encycl. Méth., 'Zooph.' p. 13; Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 326; *id.* 1834, 'Man. Act.' p. 361; Lamarck, 1836, 'Hist. Nat. etc.' ed. 2, t. ii. p. 381; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 336; Duchassaing, 1850, 'Anim. rad. Ant.' p. 17; M.-Edwards & Haime, 1851, 'Monogr. Fong.' Ann. Sci. Nat. Zool. sér. 3, t. xv. p. 129; *iid.* 1851, 'Polyp. Paléoz.' Arch. Mus. Hist. Nat. t. v. p. 129; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 83; Duchassaing & Michelotti 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 357.

Agaricia undata, var., Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 437.

Non *Agaricia undata*, Duncan, 1868, *op. cit.* pt. iv., *ibid.* vol. xxi. p. 12.

Agaricia undata, Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Undaria undata, Oken, 1815, 'Lehrb. Naturg.' Zool. Bd. i. p. 69.

Pavonia undata, Blainville, 1830, 'Zooph.' Dict. Sci. Nat. t. lx. p. 331; *id.* 1834, *op. cit.* p. 365; Duchassaing, 1847, 'Const. géol. Guad.' Bull. Soc. géol. France, sér. 2, t. iv. p. 1097.

Agaricia purpurea, Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. p. 276, pl. xv. fig. 3; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 55; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 82; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Mycedia purpurea, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 340.

Mycedium purpureum, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 357.

Mycedia gibbosa, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 341.

Mycedium gibbosum, Duchassaing & Michelotti, 1861, *op. supra cit.* p. 357.

Agaricia ? gibbosa, M.-Edwards & Haime, 1860, 'Hist. Nat. Cor.' t. iii. p. 84.

Mycedium Lessoni, Duchassaing & Michelotti, 1861, *op. cit.* p. 357; *iid.* 1866, 'Suppl. etc.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 186; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Mycedium vesparium, Duchassaing & Michelotti, 1861, *op. supra cit.* p. 357; *iid.* 1866, *op. supra cit.* p. 186; Duchassaing, 1870, *op. supra cit.* p. 31.

Agaricia vesparium, Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. p. 12.

Distribution. *Recent*: West Indies; North America and Bermuda; South America. *Fossil*: Barbados: Low-level Reefs. San Domingo: Nivajé Shale. Guadeloupe: Older or White Limestone.

Notes on Synonymy.—The *M. Lessoni* is a specimen with crowded collines. The decision to merge the species *A. undata* with *A. agaricites* seems at first of very doubtful value. The two types of calicular structure appear very distinct. A specimen from the Franks Collection (B.M. R 2482) has, however, both types on different sides of the coral; the two areas are of corresponding age and appear to have grown under the same conditions. The striking difference in appearance is therefore remarkable. Pl. XI. fig. 7 *a* shows a part of the coral with the characters of the typical *Agaricia agaricites*, and fig. 7 *b* shows a part which, if found separately, would have been referred to *A. undata*. This specimen not only unites the two species, but shows that the distinctions between the two genera *Agaricia* and *Mycedium* are valueless; for the one side of the specimen is an *Agaricia* and the other a *Mycedium*.

Species 2. Agaricia elephantotus (Pallas), 1766.

Synonymy:—

Madrepora elephantotus, Pallas, 1766, 'Elench. Zooph.' p. 290; Esper, 1789, 'Pflanzenth.' Bd. i. pp. 126–128, pl. Madr. xviii.; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3759.

Mycedium elephantotus, Oken, 1815, 'Lehrb. Naturg.' Zool Bd. i. p. 69; M.-Edwards & Haime, 1851, 'Monogr. Fong.' Ann. Sci. Nat. Zool. sér. 3, t. xv. pp. 131–132; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 74; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 186; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Agaricia elephantotus, Schweigger, 1820, 'Handb. Naturg.' p. 415; Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 329.

Pavonia elephantotus, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. pp. 323–324.

Madrepora cucullata, Solander & Ellis, 1786, 'Nat. Hist. Zooph.' p. 157, pl. xlii. figs. 1, 2; Esper, 1795, 'Pflanzenth.' Fortsetz. Bd. i. p. 83, pl. Madr. lxvii.

Agaricia cucullata, Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 373; *id.* 1816, 'Hist. Anim. s. Vert.' t. ii. 242; Lamouroux, 1821, 'Exp. Méth.' p. 54, pl. xlii. figs. 1, 2; *id.* 1824, Encycl. Méth., 'Zooph.' p. 12, pl. 484; Blainville, 1834, 'Man. Act.' p. 360, pl. 56. fig. 3; Lamarck, 1836, 'Hist. Nat. Anim. s. Vert.' ed. 2, t. ii. p. 380.

Mycedium cucullatum, Oken, 1815, 'Lehrb. Naturg.' Zool. Bd. p. i. 69.

Mycedia cucullata, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 339.

Mycedia fragilis, Dana, 1848, *ibid.* p. 341.

Mycedium fragile, Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 55; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 82; (—*a* —*is*), Pourtalès, 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. pt. 1, pl. xi. figs. 1–10, pl. xiii. figs. 1–5, pl. xiv. figs. 1–9; Ortmann, 1888, 'Stud. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 181; *id.* 1890, 'Morph. Steinkor.' Zeitschr. wiss. Zool. Bd. l. p. 288.

Agaricia fragilis, Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 11, 12.

Mycedium Danai, Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 357; *iid.* 'Suppl. Mém. Cor. Ant.' *ibid.* ser. 2, t. xxiii. p. 186; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 31.

Mycedium Sancti-Johannis, Duchassaing & Michelotti, 1866, *op. supra cit.* p. 187, pl. x. fig. 11; Duchassaing, 1870, *op. supra cit.* p. 31.

? *Mycedium Cailleti*, Duchassaing & Michelotti, 1866, *op. supra cit.* p. 187; Duchassaing, 1870, *op. supra cit.* p. 31; Pourtalès, 1874, 'Hassler Corals,' Ill. Cat. Mus. Comp. Zool. no. viii. p. 44, pl. ix. fig. 12.

Agaricia frondosa, Duchassaing & Michelotti, 1866, *op. supra cit.* pl. x. figs. 5, 6; Duchassaing, 1870, *op. supra cit.* pp. 31–32; Quelch, 1886, 'Reef Corals,' p. 118.

Distribution. Recent: West Indies; Abrolhos Banks, Brazil; Florida. *Fossil*: Barbados: Low-level Reefs, near Bridgetown (Coll. Bishop Mitchinson & Franks); San Domingo, Nivajé Shale; Guadeloupe, Older Reefs.

Notes on Synonymy.—This species is the most typical of the genus *Mycedium*; but, for reasons given in discussing the last species, the generic value of this form is regarded as quite inadmissible. The *M. cucullatum* has long been recognized as a synonym of the type-species. *M. fragile* and *M. Cailleti* appear to be both varieties based on specimens growing at a greater depth than the normal form.

Suborder **PERFORATA.**

Family MADREPORIDÆ.

Genus Madrepora, Linn., 1767.

Subgenus Eumadrepora, Brook, 1893.

Species Madrepora muricata, Linn., 1767.

Distribution. Recent: West Indies, Vera Cruz, Florida; Australia; Pacific. *Fossil*: Barbados: Low-level Reefs, Two Mile Hill, St. Michael's; near Bridgetown; Ceres; Woodstock; High-level Reefs, Welsh Town Gully (600 feet); Guadeloupe, Newer Reefs.

Notes on Synonymy.—This species was founded by Linnæus for the recent West Indian form. Its great variability was soon noticed,

but the earliest workers on the group did not perceive the necessity of subdividing it. This was done by Lamarck in 1816: he founded three species, *M. cervicornis*, *M. palmata*, and *M. prolifera*. These have been adopted by all later authors. In 1890 Heilprin and Ives[1] first suggested that the several species were probably only one. Brook in 1893 went back to the pre-Lamarckian view and merged the three best-known names of recent corals in Linnæus's original name. The examination of the collection sent by Mr. Franks from Barbados had led me previously to conclude that this course would have to be adopted. Brook has given the detailed synonymy with care,[2] and there is no need to repeat it. Duchassaing & Michelotti's type of *M. ethica* is in Turin, and is clearly only a young encrusting form of the variety *prolifera*. The types of *M. cornuta* and *M. Thomasiana* of the same authors could not be found in Turin, but the descriptions given suggest that one may safely follow Brook in reducing them to synonyms.

In regard to the recent distribution of the species, it is to be noted that Brook has recently widened it by identifying as this some specimens from Singapore, Australia, Tahiti, and Thursday Island. I have examined most of these and cannot see any point by which they could be separated from the West Indian species. In such a genus as *Madrepora* it appears, however, probable that the Pacific and Malaysian species has been developed independently. Phylogenetically it probably ought not to be included in the West Indian species, though the two are now indistinguishable one from the other.

Family PORITIDÆ.

Genus Porites, Lamarck, 1816.

Species 1. Porites clavaria, Lamarck, 1816.

Synonymy:—

Madrepora porites, Pallas, 1766, 'Elench. Zooph.' pp. 324–326; Linnæus, 1767, 'Syst. Nat.' ed. xii. p. 1279; Ellis & Solander, 1786, 'Nat. Hist. Zooph.' p. 172, pl. xlvii. figs. 1, 2; Esper, 1789, 'Pflanzenth.' Bd. i. pp. 135–139, pl. Madrep. xxi., xxi. *a*; Gmelin, 1790, 'Syst. Nat.' ed. xiii. p. 3774; Lamarck, 1801, 'Syst. Anim. s. Vert.' p. 371; Schweigger, 1820, 'Handb. Naturg.' p. 413.

Porites clavaria, Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 270; Lesueur, 1820, 'Polyp. Lamell.' Mém. Mus. Hist. Nat. t. vi. pp. 289–290, pl. xvii. fig. 17; Lamouroux, 1821, 'Exp. Méth.' p. 61, pl. xlvii. figs. 1, 2; Deslongchamps. 1824, Encyl. Méth., 'Zooph.' p. 652; Blainville, 1826, Dict. Sci. Nat. t. xliii. p. 50; *id.* 1830, *ibid.* t. lx. p. 361; *id.* 1834, 'Man. Act.' p. 396.

Porites clavaria, var. γ, Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 341.

Porites clavaria, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 554; Duchassaing, 1850, 'Anim. rad. Ant.' p. 17; M.-Edwards & Haime, 1851, 'Monogr. Porit.' Ann. Sci. Nat. Zool. sér. 3, t. xvi. p. 26; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 174; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xix. p. 358; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 42; Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 189; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 84; Lindström, 1877, 'Act. Atl.' Handl. k. Svensk. Vet.-Akad. Bd. xiv. no. 6, p. 24; Pourtalès, 1880, 'Flor. Reefs,' Mem.

[1] Proc. Acad. Nat. Sci. Phil. 1890, p. 304.

[2] G. Brook, 'Catalogue of the Madreporarian Corals in the British Museum,' vol. i. 'The Genus *Madrepora*,' 1893, pp. 23–25.

Mus. Comp. Zool. vol. vii. pt. 1, pl. xii. figs. 4–6; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.'Exped. pt. xlvi. p. 179; Rathbun, 1888, 'Cat. Porites,' Proc. U.S. Nat. Mus. vol. x. (1887) pp. 356–361, pl. xvi., pl. xvii. fig. 2, pl. xviii., pl. xix. fig. 1; Rehberg, 1892, 'Abh. Geb. Nat.' Nat. Ver. Hamburg, Bd. xii. pt. i. p. 47.

Porites flexuosa, Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 554, pl. liii. fig. 6; M.-Edwards & Haime, 1851, 'Monogr. Porites,' p. 31; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 176; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 358; *iid.* 1866, 'Suppl. etc.' p. 191; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32.

Porites flabelliformis, Lesueur, 1820, 'Polyp. Lamell.' Mém. Mus. Hist. Nat. t. vi. p. 289; Deslongchamps, 1824, Encycl. Méth., 'Zooph.' p. 652; M.-Edwards & Haime, 1851, *op. supra cit.* p. 31; *iid.* 1860, *op. supra cit.* t. iii. p. 178; Duchassaing & Michelotti, 1866, *op. supra cit.* p. 190; Duchassaing, 1870, *op. supra cit.* p. 32.

Porites Solanderi, Duchassaing & Michelotti, 1861, *op. supra cit.* p. 359; *iid.* 1866, *op. supra cit.* p. 189; Duchassaing, 1870, *op. supra cit.* p. 32; Quelch, 1886, 'Reef Corals,' p. 13.

Porites Plumieri, Duchassaing & Michelotti, 1866, *op. supra cit.* p. 190, pl. x. fig. 14; Duchassaing, 1870, *op. supra cit.* p. 32; Quelch, 1886, *op. supra cit.* p. 13.

Porites macrocephala, Duchassaing & Michelotti, 1866, *op. supra cit.* p. 189, pl. x. fig. 15; Duchassaing, 1870, *op. supra cit.* p. 32.

Porites conglomerata (pars), Lamarck, 1816, 'Hist. Nat. Anim. s. Vert.' t. ii. p. 269; *id.* 1836, *ibid.* ed. 2, t. ii. p. 434.

Porites furcata, Lamarck, 1816, *op. supra cit.* t. ii. p. 271; Deslongchamps, 1824, Encycl. Méth., 'Zooph.' p. 653; Blainville, 1826, Dict. Sci. Nat. t. xliii. p. 51; Lamarck, 1836, *op. supra cit.* ed. 2, t. ii. p. 437; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 565; M.-Edwards, 1849, 'Règne Animal, Zoophytes,' Atlas, pl. 84 *bis*; *id.* & Haime, 1851, 'Monogr. Porites,' p. 25, pl. i. figs. 1–1^{c}; *iid.* 1851, 'Polyp. Paléoz.' Arch. Hist. Nat. t. v. p. 143; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 174; Duchassaing & Michelotti, 1861, 'Mém. Cor. Ant.' p. 358; Verrill, 1864, 'List of Corals,' p. 42; Duchassaing & Michelotti, 1866, 'Suppl. etc.' p. 189; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32; Pourtalès, 1871, Ill. Cat. Mus. Comp. Zool. no. iv. p. 85; *id.* 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. pt. 1, pl. xii. fig. 7, pl. xvi. figs. 13–20; Quelch, 1886, 'Reef Corals,' p. 13; Rathbun, 1888, 'Cat. Porites,' pp. 361–364, pl. xv., pl. xvii. fig. 1; Ortmann, 1888, 'Syst. Verbr. Steinkor.' Zool. Jahrb. Bd. iii. Syst. p. 157; Heilprin, 1890, 'Corals W. Gulf Mexico,' Proc. Acad. Nat. Sci. Phil. 1890, p. 305.

Heliopora furcata, Blainville, 1830, Dict. Sci. Nat. t. lx. p. 357; *id.* 1834, 'Man. Act.' p. 392.

Porites divaricata, Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. p. 288; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 556; M.-Edwards & Haime, 1851, 'Monogr. Porit.' Ann. Sci. Nat. Zool. sér. 2, t. xvi. p. 30; *iid.* 1860, 'Hist. Nat. Cor.' t. iii. p. 178; Duchassaing & Michelotti, 1861, 'Mém Cor. Ant.' p. 358; *iid.* 1866, 'Suppl. etc.' p. 191; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32.

Porites recta, Lesueur, 1820, *op. supra cit.* p. 288, pl. xvii. fig. 16; Deslongchamps, 1824, Encycl. Méth., 'Zooph.' p. 651; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' p. 556.

Distribution. Recent: West Indies: Bermudas; Bahamas; Florida; Vera Cruz; ? Red Sea & Indian seas. *Fossil*: Barbados: Low-level Reefs near Bridgetown (Franks & Mitchinson Coll.).

Notes on Synonymy.—According to the British Association rule that the same word is not to be used as the generic and specific names of the same animal, this species cannot be called *Porites porites* (Linn.). The specific name has therefore to be dropped, and the next one taken. *P. clavaria* and *P. furcata* were proposed at the same time, but, as *P. clavaria* comes first and has been generally regarded as the most typical, it is best to accept that.

There has been an universal consensus of opinion since the days of Lamarck that *P. clavaria* and *P. furcata* are distinct. Nevertheless, I cannot but feel that it is necessary to merge them. Their distinction has been based on three characters: firstly, the height of the epitheca; secondly, the shape of the ends of the branches; thirdly, the structure of the calices. There is a fine series of specimens of both forms in the Museum of Comparative Zoology at Cambridge, Mass., many of which were labelled by Pourtalès. An examination of these shows that the three characters are each of them

useless. Thus in the case of the epitheca, in a specimen labelled *P. furcata* which is 134 mm. high, in one branch the epitheca runs up to within 29 mm. of the top on one side, while on the other it ends off 62 mm. from the same point. The shape of the ends of the branches appears at first sight more distinctive, and it is by this character that the specimens have been generally determined; but in a large branching specimen at Cambridge the variation in the compression of the branches varies as follows :—

$$\frac{\text{Longer diameter}}{\text{Wider diameter}} = \frac{9}{15'}\ \frac{8}{15'}\ \frac{6}{13'}\ \frac{7}{7{\cdot}5'}\ \frac{8}{13'}\ \frac{8}{10}.$$

The third of these shows the compression of *P. furcata*, but the fourth is practically circular in section. This one specimen has typical representatives of both the supposed species.

The last character is the supposed absence of a tubercular columella in *P. furcata* and its presence in *P. clavaria*. But there are specimens at Cambridge, Mass., labelled *P. furcata*, with a well-marked columella. In some the columella can be seen in the older parts of the colony, while it is absent in the newer calices. If this character be of any use, then Pourtalès and Quelch have reversed the correct names of the species. Rathbun had previously remarked that the calicinal characters are useless, though he keeps the species distinct: he says that Pourtalès's figures of the calicinal structures of *clavaria* and *furcata* in the 'Memoir on the Florida Reefs' (pl. xvi. fig. 14, & pl. xii. fig. 5) would do indifferently for either species. There seems, therefore, no valid distinction between them. In one large mass labelled *P. furcata* by Pourtalès, in some calices there is no trace of a columella, and a circle of pali surround a central space; in others there is a small columella; in yet others there is a columella as large as one of the pali.

Species 2. Porites astræoides, Lamarck, 1816.

Synonymy :—

Porites astræoïdes, Lamarck, 1816, 'Hist. Nat. Anim. s.Vert.' t. ii. p. 269; Lesueur, 1820, 'Polyp. Lam.' Mém. Mus. Hist. Nat. t. vi. p. 287, pl. xvi. fig. 15; Blainville, 1834, 'Man. Act.' p. 395, pl. lxi. fig. 5; Ehrenberg, 1834, 'Cor. roth. Meer.' Abh. k. Akad. Wiss. Berlin, 1832, p. 343; Lamarck, 1836, *op. cit.* ed. 2, t. ii. p. 435; Dana, 1848, 'Zooph. Explor. Exped. Wilkes,' vol. viii. p. 561; Duchassaing, 1850, 'Anim. rad. Ant.' p. 17; M.-Edwards & Haime, 1860, 'Hist. Nat. Cor.' t. iii. p. 178; Verrill, 1864, 'List of Corals,' Bull. Mus. Comp. Zool. vol. i. p. 42; Duncan, 1868, 'Foss. Cor. W. Ind.' Quart. Journ. Geol. Soc. vol. xxiv. p. 12; Pourtalès, 1871, 'Deep-Sea Corals,' Ill. Cat. Mus. Comp. Zool. no. iv. p. 85; *id.* 1880, 'Flor. Reefs,' Mem. Mus. Comp. Zool. vol. vii. pt. i. pl. xvi. figs. 1–12, 21–22; Quelch, 1886, 'Reef Corals,' Zool. 'Chall.' Exped. pt. xlvi. pp. 11, 13, 182; Rathbun, 1888, 'Cat. Species *Porites* U.S. Nat. Mus.' Proc. U.S. Nat. Mus. vol. x. (1887) pp. 354–355; Heilprin, 1890, 'Cor. W. Gulf Mex.' Proc. Acad. Nat. Sci. Phil. 1890, p. 305.

Neoporites astræoïdes, Duchassaing & Michelotti, 1866, 'Suppl. Mém. Cor. Ant.' Mem. R. Accad. Sci. Tor. ser. 2, t. xxiii. p. 192; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32.

Neoporites incerta, Duchassaing & Michelotti, 1866, 'Suppl. etc.' p. 193; Duchassaing, 1870, 'Rev. Zooph. Ant.' p. 32.

Porites Collegniana (*non* Michelin), Duncan, 1863, 'Foss. Cor. W. Ind.' pt. i., Quart. Journ. Geol. Soc. vol. xix. p. 437.

Distribution. Recent: West Indies; Florida; Vera Cruz. *Fossil*: Barbados: Low-level Reefs near Bridgetown; High-level Reefs, Castle Grant (1070 feet); Trinidad, St. Croix; San Domingo, Nivajé Shale.

Table of Distribution of Corals.

	Recent.				Fossil.									
		Atlantic Coasts.			Barbados.			San Domingo.			Guadeloupe.			
	West Indies.	N. Amer. & Bermuda.	S. Amer.	Indo-Pacific.	Low Level.	High Level.	Trinidad.	Nivajé Shale.	Tufaceous Limest.	Antigua Marl.	Newer Reefs.	Older or White Limest.	Bermuda.	Miscellaneous.
1. *Madracis decactis* (Lym.)	*	*	...	...	*	...	...	*	...	...	...	...	*	
2. *Lithophyllia cubensis* (Ed. & H.)	*	*	...	...	*									
3. „ *lacera* (Pall.)	*	*	...	...	*	...	...	...	...	...	...	...	...	Jamaica.
4. „ *Walli* (Dunc.)	...	...	...	...	*	...	...	...	...	...	...	...	...	Jamaica.
5. *Eusmilia fastigiata* (Pall.)	*	*	...	...	*	*	...	...	...	...	*			
6. „ *Knorri*, Ed. & H.	*	...	...	...	*									
7. *Mussa angulosa* (Pall.)	*	...	...	...	*									
8. *Dendrogyra cylindrus*, Ehr.	*	...	...	...	*									
9. *Pectinia mæandrites* (Pall.)	*	...	...	...	*	...	...	...	...	...	*			
10. *Diploria cerebriformis* (Lam.)	*	*	...	...	*	*								
11. *Manicina areolata* (Pall.)	*	*	...	*	*	...	...	*	...	...	*			
12. *Mæandrina filograna* (Esper)	*	*	...	...	*	*	...	*						
13. *Mycetophyllia Lamarcki*, Ed. & H.	*	...	...	...	*	...	...	...	...	...	...	...	*	
14. *Colpophyllia gyrosa* (Ell. & Sol.)	*	*	...	...	*	*	...	...	...	...	*			
15. *Hydnophora latefundata*, n. sp.	...	...	...	...	...	*	*							
16. *Dichocœnia Stokesi*, Ed. & H.	*	...	...	...	*	...	...	*	*					
17. *Lamellastræa Smythi*, Dunc.	...	...	...	...	...	*	...	...	...	*				
18. *Favia ananas* (Pall.)	*	*	...	...	*	...	...	...	...	...	*			
19. *Orbicella radiata* (Ell. & Sol.)	*	*	*	...	*	*	*	*	*	*	*	*	*	
20. „ *acropora* (Linn.)	*	*	...	?	*	*	*	...	...	*				
21. *Solenastræa stellulata* (Ell. & Sol.)	*	...	...	...	...	*	...	...	*	...	...	...	...	Jamaica.
22. *Cyphastræa costata*, Dunc.	*	...	...	...	*	*	...	*	...	...	...	...	...	„ & Barbuda.
23. *Echinopora Franksi*, n. sp	*?	...	...	...	*									
24. *Stephanocœnia intersepta* (Esper)	*	...	...	...	*	...	*	(Silt.)	...	...	...	*		
25. *Astræa radians* (Pall.)	*	*	...	...	*	...	...	...	...	...	...	...	...	Bahamas.
26. „ *siderea* (Ell. & Sol.)	*	*	*	...	*	*	...	*	...	...	*	...	...	Jamaica.
27. *Agaricia agaricites* (Pall.)	*	*	*	...	*	...	...	*	...	...	...	*		
28. „ *elephantotus* (Pall.)	*	...	...	...	*									
29. *Madrepora muricata* (Linn.)	*	*	...	*	*	*	...	...	...	...	*			
30. *Porites clavaria*, Lam.	*	*	*	?	*									
31. „ *astræoïdes*, Lam.	*	*	...	...	*	*	*	*						

III. List of Mollusca from the Low-level Reefs of Barbados.

In consideration of the differences between the corals of the raised reefs of Barbados and those still living in adjoining seas, it seemed advisable to examine the fossil mollusca. Mr. Jukes-Browne made a collection for this purpose from some reefs at Ceres, at the height of about 70 feet above the sea; a list of these was published in 1891.[1] The collection, however, was a comparatively small one, numbering only twenty-seven species. Since then the opportunity for a careful comparison between the recent and fossil molluscan faunas has been afforded by the kindness of the Rt. Rev. Bishop Mitchinson, who, during his residence in Barbados, made a large collection of shells from the raised reefs near Bridgetown. This collection, numbering over 1000 specimens belonging to over 140 species, he has generously presented to the British Museum (Nat. Hist.). That it has been possible to work out the collection is due to the kindness of Mr. E. A. Smith; he has himself named most of the species and checked every doubtful determination, often by comparison with D'Orbigny's types, which are now preserved in the Zoological Department of the Museum. For the amount of trouble which Mr. Smith has taken in this work I must express to him my best thanks.

The list is arranged in accordance with the classification adopted in Fischer's 'Manuel de Conchologie.' Many of the names are probably not of specific value; they have been given only to West Indian varieties of more widely distributed species. As the list is, however, mainly useful for the study of distribution, these slight differences are of value. The distribution is taken in the main from the works of Paetel and E. A. Smith. In deference to the opinion of the latter, Tryon's localities and some mistaken records in Paetel have been omitted.

A list of 53 species was published by Sir R. Schomburgk,[2] but the exact horizons from which these came are not stated.

[1] A. J. Jukes-Browne & J. B. Harrison, 'The Coral Rocks of Barbados and other West Indian Islands,' Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 225.

[2] R. H. Schomburgk, 'History of Barbados,' 1847, pp. 562–565.

Name.	Author of Species.	Fossil: Barbados. Bridgetown.	Fossil: Barbados. Ceres.	Recent. West Indies.	Recent. Atlantic coast of U.S.A.	Recent. St. Helena.	Recent. Canary Islands, Azores.	Recent. W. coast of Africa.	Recent. Mediterranean.	Recent. Brazil.	Recent. Panama.	Recent. Indo-Pacific.
Class PTEROPODA.												
Cavolinia longirostris	Lesueur	—	...	—	...	...	—	—	—	—	—	—
Class GASTROPODA.												
Order 1. PULMONATA.												
Fam. Auriculidæ.												
Melampus flavus	Gmel.	—	...	—	...	...	...	—				
„ „ var.												
Order 2. OPISTHOBRANCHIATA.												
Fam. Bullidæ.												
Bulla striata	Brug.	—	—	—	...	...	...	—	—	—		
„ *solida* (non Gmel.)	A. Ad.	—	...	—								
Order 3. PROSOBRANCHIATA.												
A. Toxoglossa.												
Fam. Conidæ.												
Conus (*Chelyconus*) *pygmæus*	Reeve	—	...	—								
„ (*Stephanoconus*) *Ximenes*	Gray	—										
„ („) *verrucosus*	Hwass.	—	...	—	...	...	...	—				
„ („) *nebulosus*	Sol.	—	...	—								
„ (*Hermes*) *granulatus*	Linn.	—	...	—								
Pleurotoma (*Crassispira*) *fuscescens*	Gray	—	...	—								
„ „ *quadrifasciata*	„	—	...	—								
Fam. Cancellariidæ.												
Cancellaria reticulata	Linn.	—	...	—	—							
B. Rhachiglossa.												
Fam. Olividæ.												
Oliva (*Strephona*) *litterata*	Lam.	—	...	—	—	...	...	...	...	—		
„ (*Olivella*) *jaspidea*	Gmel.	—	—	—								
Fam. Marginellidæ.												
Volvaria avena	Val.	—	...	—								
Fam. Volutidæ.												
Voluta musica	Linn.	—	...	—								

TABLE (*continued*).

Name.	Author of Species.	Fossil: Barbados.		Recent.								
		Bridgetown.	Ceres.	West Indies.	Atlantic coast of U.S.A.	St. Helena.	Canary Islands, Azores.	W. coast of Africa.	Mediterranean.	Brazil.	Panama.	Indo-Pacific.
Fam. FASCIOLARIIDÆ.												
Latirus spadiceus	Reeve	–	…	–	…	…	…	…	…	…	–	
Leucozonia cingulifera	Lam.	–	…	–	–	…	…	…	–	…	–	
,, ,, var. *angularis*	Reeve	…	–	–	–	…	…	…	…	…	…	
Fam. TURBINELLIDÆ.												
Vasum cœstum	Brod.	–	…	–	…	…	…	…	…	…	–	
Pyrula (*Melongena*) *melongena*	Linn.	–	…	–	…	…	…	…	…	…	…	
Fam. BUCCINIDÆ.												
Pollia (*Tritonidea*) *coromandeliana*	Lam.	–	…	–	…	…	…	…	…	–	…	
Pisania pusio	Linn.	–	…	–	…	…	…	…	…	…	–	
Phos (*Strongylocera*) *pallida*	Powis	–	…	–	…	…	…	–	…	…	–	–
Fam. NASSIDÆ.												
Nassa (*Phrontes*) *ambigua*	Mont.	–	…	–	…	…	…	–	…	…	…	
,, ,, *vibex*	Say	–	…	–	–	…	…	…	…	–	…	
Fam. COLUMBELLIDÆ.												
Columbella (*Pygmæa*) *mercatoria*	Linn.	–	–	–	–	…	…	…	…	…	…	
,, (*Engina*) *turbinella*	Kiener	–	…	–	…	…	…	…	…	…	…	
,, (*Conidea*) *ovuloides*	C. B. Ad.	–	…	–	…	…	…	…	…	…	…	
Fam. MURICIDÆ.												
Murex Toupiollei	Born	–	…	–	…	…	…	…	…	…	…	
,, (*Haustellum*) *messorius*	Sow.	–	–	–	…	…	…	…	…	…	…	
Purpura (*Thalessa*) approx. *speciosa*	Val.	–	…	…	…	…	…	…	…	…	–	
,, (*Stramonita*) *fasciata*	Reeve	–	…	–	…	…	…	–	…	…	…	
Ricinula (*Sistrum*) *nodulosa*	C. B. Ad.	–	–	–	…	…	…	…	…	–	…	
Fam. CORALLIOPHILIDÆ.												
Coralliophila costata	Blainv.	–	…	…	…	…	…	…	…	…	–	
,, *abbreviata*	Lam.	–	…	–	…	…	…	–	…	–	–	–
,, *nivea*	C. B. Ad.	–	…	…	…	…	…	…	…	…	–	
C. TÆNIOGLOSSA.												
Fam. TRITONIDÆ.												
Triton Tritonis	Linn.	–	…	–	…	…	…	…	–	…	…	–
,, (*Simpulum*) *pilearis*	Linn.	–	…	–	…	…	…	…	…	–	…	–
,, (*Colubraria*) *testaceus*	Mörch	–	…	–	…	…	…	…	…	…	…	…
,, (*Lotorium*) *Antillarum*	D'Orb.	–	…	–	…	…	…	…	…	…	…	–
Ranella (*Lampas*) *Thomæ*	,,	–	…	–	…	…	…	…	…	…	…	–
,, ,, aff. *affinis*	Brod.	–	…	…	…	…	…	…	…	…	…	–

TABLE (*continued*).

Name.	Author of Species.	Fossil: Barbados. Bridgetown.	Fossil: Barbados. Ceres.	Recent. West Indies.	Recent. Atlantic coast of U.S.A.	Recent. St. Helena.	Recent. Canary Islands, Azores.	Recent. W. coast of Africa.	Recent. Mediterranean.	Recent. Brazil.	Recent. Panama.	Recent. Indo-Pacific.
Fam. CASSIDÆ.												
Cassis (*Cassidea*) *testiculus*	Linn.	—	...	—	...	—	...	—				
,, (*Semicassis*) *undulata* [*granulosa*, Brug.]	Gmel.	—	...	—	...	...	...	...	—			
Oniscia (*Oniscidea*) *oniscus*	Linn.	—	...	—								
Fam. DOLIIDÆ.												
Dolium perdix	Linn.	—	...	—	...	...	...	—	...	—		—
Fam. CYPRÆIDÆ.												
Cypræa cinerea	Gmel.	—	...	—								
,, ,, var. *clara*	Gask.	—	...	—								
,, *exanthema*	Linn.	—	...	—	—							
,, (*Luponia*) *spurca*	,,	—	—	—	...	—	...	—				
Trivia vitrea	Gask.	—	...	...	...	...	...	...	...	...	...	—
Cyphoma (*Ultimus*) *gibbosa*	Linn.	—	...	—	—	...	...	...	...	—		
,, ,, *intermedia*	Sow.	—	...	—	...	...	...	...	...	—		
Fam. STROMBIDÆ.												
Strombus gigas	Linn.	—	...	—	—	...	...	...	...	—		
,, *pugilis*	,,	—	...	—	—	...	...	...	...	—		
,, (*Monodactylus*) *bitubercu-latus* [*lobatus*, Sow.]	Lam.	—	...	—	...	...	...	...	...	—		
Fam. CERITHIIDÆ.												
Cerithium atratum	Born	—	—	—	—							
,, *litteratum*	,,	...	—	—	—							
,, *eburneum*	Brug.	—	—	—								
Fam. MODULIDÆ.												
Modulus (*Modulus*) *lenticularis*	Chemn.	—	...	—								
Fam. PLANAXIDÆ.												
Planaxis succinctus	A. Ad.	—	...	—	...	...	—					
Fam. LITTORINIDÆ.												
Littorina (*Melaraphe*) *ahenea*	Reeve	...	—	—	—	...	..	—				
Tectarius muricatus	Linn.	—	...	—	—							
Fam. SOLARIIDÆ.												
Solarium (*Torinia*) *cyclostomum*	Menke	—	...	—								
Fam. LITROPIDÆ.												
Alaba tervaricosa	C. B. Ad.	—	...	—								

TABLE (*continued*)

Name.	Author of Species.	Fossil: Barbados. Bridgetown.	Fossil: Barbados. Ceres.	Recent. West Indies.	Recent. Atlantic coast of U.S.A.	Recent. St. Helena.	Recent. Canary Islands, Azores.	Recent. W. coast of Africa.	Recent. Mediterranean.	Recent. Brazil.	Recent. Panama.	Recent. Indo-Pacific.
Fam. RISSOIDÆ.												
Rissoina sagraiana	D'Orb.	–	...	–								
Fam. HIPPONIDÆ.												
Hipponyx antiquatus	Linn.	–	–	–	–	...	...	–	...	...	–	–
Calyptræa (*Mitrularia*) *Dillwyni*	Gray	–	...	–	...	...	...	...	...	...	–	–
Fam. CAPULIDÆ.												
Pileopis (*Capulus*) *intortus*	Meusch.	–	...	–	–	...	...	...	...	...	...	–
Crepidula (*Crepipatella*) *aculeata*	Gmel.	–	...	–	–	...	...	...	...	–	–	–
Fam. NATICIDÆ.												
Natica marochiensis	Gmel.	–	–	–	...	...	...	–	...	...	–	–
„ (*Pollinices*) *uberina*[1]	D'Orb.	–	...	–	...	...	–	...	...	–		
„ „ *porcellanea*	„	–	–	–	...	–	–	...	...	...	...	–
Fam. PYRAMIDELLIDÆ.												
Obeliscus dolobratus	Linn.	–	–	–	...	–	...	–				
D. RHIPIDIGLOSSA.												
Fam. NERITIDÆ.												
Nerita (*Peloronta*) *peloronta*	Linn.	–	...	–	–							
„ „ *tessellata*	Gmel.	–	...	–	–							
Fam. TURBINIDÆ.												
Pachypoma (*Astralium*) *imbricata*	Gmel.	–	...	–								
Fam. TROCHIDÆ.												
Livona pica	Linn.	–	...	–	–							
Fam. FISSURELLIDÆ.												
Fissurella (*Crenides*) *barbadensis*	Gmel.	–	...	–	–							
Lucapina græca	Linn.	–	...	...	...	...	...	–	–			
„ „ var. *Listeri*	D'Orb.	–	...	–								
„ *cancellata*	Sow. (Sol. MS.)	–	...	–								
Emarginula imbricata	A. Ad.	–	...	...	...	...	...	...	...	...	...	–

[1] The specimen is the *P. uberina* as usually interpreted; D'Orbigny's type-specimen, however, has not an especially straight callosity.

TABLE (*continued*).

Name.	Author of Species.	Fossil: Barbados.		Recent.									
		Bridgetown.	Ceres.	West Indies.	Atlantic coast of U.S.A.	St. Helena.	Canary Islands, Azores.	W. coast of Africa.	Mediterranean.	Brazil.	Panama.	Indo-Pacific.
Class LAMELLIBRANCHIATA.												
Order 1. TETRABRANCHIA.												
Fam. OSTREIDÆ.												
Ostrea canadensis	Lam.	—	...	...	—							
„ *frons*	Linn.	—	...	—								
Fam. SPONDYLIDÆ.												
Spondylus ictericus	Reeve	—	...	...	—							
„ *electrum?*	„	—	...	—								
Plicatula cristata	Lam.	—	...	—								
Fam. LIMIDÆ.												
Lima multicostata	Sow.	—	...	...	—	...	...	...	...	...	...	—
Ctenoides scabra	Born	—	...	—								
Fam. PECTINIDÆ.												
Pecten exasperatus	Sow.	—	...	—								
„ *vestalis*	Reeve	—	...	—								
Vola (*Janira*) *modesta*	Reeve	—	...	—								
„ „ *ziczac*	Linn.	—	...	—								
Fam. MYTILIDÆ.												
Mytilus exustus	Linn.	—	...	—	...	...	...	...	...	—		
Modiola cinnamomina	Chem.	—	...	...	...	...	...	...	...	...	...	—
Lithodomus corrugatus	Phil.	—	...	—								
Fam. ARCIDÆ.												
Arca imbricata	Brug.	—	...	—	...	...	...	...	...	...	...	—
Barbatia (*Acar*) *Adamsi*	Shuttl.	...	...	—	—							
„ „ *domingensis* [*squamosa*, Linn.]	Lam.	—	...	—	...	—	—	—	...	...	...	—
„ *candida*	Chem.	—										
„ *fusca*	Brug.	—	...	—	...	...	...	...	...	...	...	—
Anomalocardia Deshayesi	Hanl.	—	...	...	...	...	...	...	...	...	...	—
Pectunculus pectinatus	Gmel.	—	...	—	—							
„ „ var. *pallium*	Reeve	—	...	...	...	...	...	...	...	...	...	—
„ (*Axinæa*) *pennaceus*	Lam.	—	...	—								
„ „ „ var. *lineatus*	Reeve	—	...	—								

TABLE (*continued*).

Name.	Author of Species.	Fossil: Barbados. Bridgetown.	Fossil: Barbados. Ceres.	Recent. West Indies.	Recent. Atlantic coast of U.S.A.	Recent. St. Helena.	Recent. Canary Islands, Azores.	Recent. W. coast of Africa.	Recent. Mediterranean.	Recent. Brazil.	Recent. Panama.	Recent. Indo-Pacific.
Fam. CARDIIDÆ.												
Cardium serratum	Linn.	–	…	–	–							
„ (*Bucardium*) *lima*	Gmel.	–	…	…	…	…	…	…	…	…	…	–
Ctenocardia (*Fragum*) *medium*	Linn.	–	…	–	…	…	–	–				
„ „ aff. *graniferum*	Brod.	–	…	…	…	…	…	…	…	–		
Fam. CHAMIDÆ.												
Chama macrophylla	Chem.	–	…	–								
„ *ruderalis*	Lam.	–	…	–								
Fam. CYPRINIDÆ.												
Cypricardia coralliophaga	Lam.	–	…	…	…	…	…	…	…	…	…	–
Basterotia quadrata	Hinds	–	…	–								
Fam. VENERIDÆ.												
Caryatis albida	Gmel.	–	…	–								
Anaitis paphia	Linn.	–	…	–								
Chione multicostata	Sow.	–	…	…	…	…	…	…	…	…	–	
„ *cerina*	C. B. Ad.	…	…	–	–							
„ (*Ventricola*) *rugosa*	Gmel.	–	…	…	…	…	…	…	…	–		
„ (*Omphaloclathrum*) *cancellata*	Linn.	–	…	–	–							
Venerupis Iris	Linn.	–	…	–	…	…	–	–	–			
Fam. PETRICOLIDÆ.												
Chœristodon lapicidum	Chem.	–	…	–	…	…	…	…	…	…	…	–
Fam. UNGULINIDÆ.												
Diplodonta rotundata (var. *subglobosa*)	Mont.	–	…	–	…	…	–	–	–			
Fam. PSAMMOBIIDÆ.												
Asaphis defloratus	Linn.	–	–	–	…	…	…	…	…	…	…	–
„ *coccinea*	Mart.	–	…	–								
Order 2. DIBRANCHIA.												
Fam. LUCINIDÆ.												
Lucina columbella	Lam.	–	–	–	…	…	–	–				
„ *jamaicensis*	Lam.	…	–	–								
Codakia exasperata	Reeve	–	…	–								
„ *tigerina*	Linn.	–	…	–								
„ (*Myrtea*) *imbricatula*	C. B. Ad.	–	…	–	…	…	–					
„ „ *costata*	D'Orb.	–	–	–								
Loripes chrysostomus	Phl.	–	…	–								
Divaricella dentata	Wood	–	–	–								

TABLE (*continued*).

Name.	Author of Species.	Fossil: Barbados.		Recent.									
		Bridgetown.	Ceres.	West Indies.	Atlantic coast of U.S.A.	St. Helena.	Canary Islands, Azores.	W. coast of Africa.	Mediterranean.	Brazil.	Panama.	Indo-Pacific.
Fam. TELLINIDÆ.												
Tellina (*Musculus*) *radiata*	Linn.	—	...	—								
„ „ *brasiliana*	Splgr.	—	...	...	...	...	...	...	...	—		
„ (*Tellinella*) *decora*	Say.....	—	—	—	—							
„ „ *interrupta*	Sol.	—	—	—	...	...	...	...	...	—		
„ (*Peronæoderma*) *rubescens* ...	Hanl.	—	...	—	...	...	...	...	...	...	—	
„ (*Arcopagia*) *fausta*	Pult.	—	...	—								
„ (*Metis*) *ephippium*	Splgr.	—	—	...	...	...	...	...	...	...	...	—

(Percentages of distribution have not been given: these can alone be usefully compiled by a specialist on the Mollusca, for the above species are certainly not of equal value. The list is, however, conclusive as to the fauna being practically identical with that of the present West Indian seas.)

IV. THE OCCURRENCE OF THE OCEANIC SERIES IN CUBA.

The fact that the Oceanic deposits were known only in Barbados, and in a less typical form in Trinidad, to some extent detracted from their significance. For, though Barbados is not itself a volcanic island, it occurred near a great volcanic line, and thus great local oscillations might easily have occurred. The absence of the deep-sea deposits in the central West Indian Islands seemed to show that their geographical range was but limited. The only known bed approximating to this type in the central West Indies was the Pteropod Marl of Jamaica, which, though clearly of deep-sea origin, did not imply any such abyssal conditions as do the radiolarian oozes.

I was, therefore, much interested when examining the collection of coral rocks formed by Prof. Crosby in Cuba, and now preserved in the Museum of the Boston Society of Natural History, to find among them some specimens of radiolarian marls. The specimens illustrated Prof. Crosby's well-known paper[1] on the raised reefs of Cuba, but this contained no information as to the mode of occurrence of the marls. The author, however, kindly described to me their position, which is at the base of the coral-rocks; the two series seem to occur in exactly the same relative positions as the

[1] W. O. Crosby, 'On the elevated Coral Reefs of Cuba,' Proc. Boston Soc. Nat. Hist. vol. xxii. (1883) pp. 124–130.

corresponding deposits in Barbados. Prof. Crosby, moreover, most generously gave me samples of the three principal varieties. Sections were subsequently prepared from these, and my guess as to their character was fully confirmed. They proved to be typical, pure oceanic oozes. This fact was announced in the discussion on Messrs. Jukes-Browne and Harrison's paper on Barbados.[1] At that time I had not succeeded in isolating the radiolaria so as to be able to identify the species. This, however, has now been kindly done by Mr. W. Murton Holmes, whose skill in mounting microscopic objects of this sort is well known. I must express to him my indebtedness for the time which he devoted to this task.

The accompanying list of radiolaria from these Cuban marls is very incomplete. It could easily be doubled by a more detailed examination of the slides. It is, however, sufficient for its purpose. All the species in the list are also found in Barbados. The common and conspicuous species are the same in both faunas. Some rarer forms have not apparently been recorded from Barbados, but every one agrees that the list of species from that island is still very imperfect. Until the Barbados fauna has been better worked out, the discovery of many species from Cuba, not recorded in it, would prove nothing.

The exact locality at which the Cuban radiolarian marls were collected is at Baraçoa, on the north side of the extreme eastern end of the island. Mr. R. T. Hill[2] has recently described the geology of this area. He describes a series of siliceous and argillaceous beds with radiolaria along the coast at Baraçoa, and says that they probably underlie the 'yellow beds;'[3] these latter contain many fossils, which enable him to identify them as Miocene. No doubt these siliceous beds are the radiolarian marls. Hill says that they are vertical and contorted, and are 500 feet in thickness. His description of the field-relations of these beds is not as detailed as one could wish, and leaves room for a little doubt as to their exact mode of occurrence. Mr. Hill's remark[4] that there is no evidence of subsidence after the beginning of the Tertiary is also rather puzzling, unless it be a verbal misprint. Nevertheless it appears probable that the marls occur interstratified with Miocene limestones, and are in places overlain unconformably by the Pleistocene coral-reefs.

List of the Radiolaria.

The following list contains only a small proportion of the species in the collection. The 33 species determined are, however, sufficient to prove the practical identity of the faunas, for they belong to the five suborders Sphæroidea, Prunoidea, Discoidea, Spyroidea, and Cyrtoidea, and represent 17 families and 25 genera. The list there-

[1] Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 226.

[2] R. T. Hill, 'Notes on the Tertiary and later History of the Island of Cuba,' Amer. Journ. Sci. ser. 3, vol. xlviii. (1894) pp. 196–212.

[3] *Ibid.* pp. 199–200.

[4] *Ibid.* p. 210.

fore shows that the resemblance between the radiolarian faunas of Cuba and Barbados extends to a wide range of forms:

Cerasosphæra entactinia (Ehr.).
Stylosphærella liostylus, Ehr.
Staurolonchantha aperta (Ehr.).
Haliometta oculatum (Ehr.).
Xiphatractylis spinulosum (Ehr.).
Xiphatractium radiosum (Ehr.).
„ aff. *radiosum* (Ehr.).
Heliodiscella helianthus (Ehr.).
„ *triactinus*[1] (Ehr.).
Stylodictyon gracilis, Ehr.
„ *multispina*, Haeck. (syn. *Forbesi*, Ehr.).
Stylodictula setigera, Ehr.
Stylospira echinastrum, Ehr.
Stylotrochiscus rhabdostylus (Ehr.).
Petalospyrantha foveolata, Ehr.
Lophospyris prox. *echinus*, Ehr.
Gorgospyrium pentas[2] (Ehr.).
Desmopyris anthocyrtoides (Bütschli).
Sphærospyris sphæra (Bütschli).
Lychnocanissa hirundo, Ehr.
Lychnocanoma crassipes, Ehr.
Anthocyrtella ventricosa, Ehr.
Anthocyrtissa grossularia, Ehr.
Podocyrtecium brevipes, Ehr.
Podocyrtidium papale, Ehr.
„ *mitra*, Ehr.
Theopera luscinia (Ehr.).
Cyclampterium spatiosum, Ehr.
Clathrocyclia puella-sinensis (Ehr.).
Theocorypha cylindrica (Ehr.).
Theocorythium persipeltis (Ehr.).
Cyrtostrobus picus (Ehr.).
Lithomitrella acephalum (Ehr.).
Artocyrtis montiparum (Ehr.).

V. Additions to the Fossil Fauna of Antigua.

Two small but valuable collections from Antigua have recently been sent to me for examination. One consists of some mollusca and corals from the 'upper limestones' (of Purves); it has been forwarded by Mr. Jukes-Browne. The mollusca belong to the genera *Melanopsis* and *Turritella*. Mr. Edgar Smith has kindly examined these with great care, but is unable to identify them with any recent species. The best-preserved coral is a specimen of *Prionastræa diversiformis* (Mich.), a typical species of the Italian Miocene (Helvetian). It has been previously recorded from Antigua by M. Purves.[3]

I cannot name the other corals without more material for comparison from the Miocene of Piedmont.

The second collection was sent by J. Vincent Forrest, Esq., M.B. It is of much interest, as it contains two of the echinoids which are most typical of the West Indian Oligocene. They are *Echinanthus* (or *Diplothecanthus* of Duncan) *concavus* (Cott.)[4] and *E. Antillarum* (Cott.).[5] No echinoids had been previously recorded from the island. These are of great value, as establishing the correlation of the beds in which they occur with those of St. Bartholomew and Anguilla.

The coral described by Duncan as *Alveopora dædalea* is also

[1] Haeckel (Zool. 'Chall.' Exped. vol. xviii. pt. 1, 1887; Radiolaria, vol. i. p. 432) has renamed this species *tripodiscus*; as the reason for the change is not apparent, I retain the earlier one.

[2] Haeckel, *op. cit.* p. 1070, has renamed this species *Ehrenbergii*.

[3] J. C. Purves, 'Esquisse géologique de l'île d'Antigoa,' Bull. Mus. Hist. Nat. Belg. vol. iii. (1884) p. 289.

[4] G. Cotteau, 'Description des Echinides tertiaires des îles St. Barthélemy et Anguilla,' K. Svensk. Vet.-Akad. Handl. vol. xiii. no. 6 (1875), p. 16, pl. ii. figs. 4–8.

[5] *Ibid.* p. 15, pl. ii. figs. 1–3.

represented in the collection. There is moreover a *Lithophyllia cubensis* (M.-Ed. & H.); it is said to be derived from some recent raised reefs, but the exact locality is not stated.

These two collections conclusively prove that the Antigua series of cherts and limestones are neither Pleistocene nor Pliocene, as has recently been suggested. They are certainly either Oligocene or Miocene—probably the former.

VI. The Correlation of the Barbados Rocks and its Bearing on the History of the Caribbean Area.

The Barbados Sequence.—The island of Barbados is composed of a series of rocks which may be classified as follows:—

Raised Coral Reefs.	Low-level Reefs.
	High „ „
Oceanic Series.	*Archæopneustes abruptus*-Limestone.
	Thalassic Marls.
Scotland Beds.	

That these occur in the above sequence there can be now no doubt, thanks to the labours of Messrs. Jukes-Browne and Harrison[1] and Col. H. W. Feilden[2]; but in the first geological map and description of the island,[3] the rocks now known as the Oceanic Series were said to overlie the coral-limestones, while Schomburgk[4] described the deep-sea marls as interstratified with the Scotland Beds.

The Age of the Coral-Limestones.—The Low-level Reefs yield a rich molluscan fauna (see Part III. of this paper), which proves that these are of late Pleistocene age. The determination of the date of the other divisions of the sequence is a difficult task. Let us in the first place consider the correlation of the High-level Reefs. These are stratigraphically continuous with those of the lower levels, and it might at first sight appear unnecessary to separate them. There are, however, distinct differences in the fauna. Of the 31 species of corals found in the raised reefs of Barbados, 4 species and 3 genera are not known to occur at the present time in the West Indian seas. Nine of the recent species are recorded from the Nivajé Shale of San Domingo, which is assigned by Gabb[5] to the Middle Miocene. This would therefore appear to suggest that the corals have so long a

[1] J. B. Harrison and A. J. Jukes-Browne, 'The Geology of Barbados, being an Explanation of the Geological Map,' etc. (1890), 8vo. 64 pp. and map; also 'The Geology of Barbados.—Part I. The Coral-Rocks of Barbados and other West Indian Islands,' Quart. Journ. Geol. Soc. vol. xlvii. (1891) pp. 197–250, and 'Pt. II. The Oceanic Deposits,' *ibid.* vol. xlviii. (1892) pp. 170–226.

[2] H. W. Feilden, 'On the Birds of Barbados,' Ibis, ser. 6, vol. i. (1889) pp. 478–479.

[3] Jas. Dutt. Maycock, 'Flora Barbadensis . . . . to which is prefixed a Geological Description of the Island,' London, 1830, pp. 15–17, pls. i., ii.

[4] R. H. Schomburgk, 'The History of Barbados,' 1847, pp. 546–557.

[5] W. M. Gabb, 'On the Topography and Geology of Santo Domingo,' Trans. Amer. Phil. Soc. new ser. vol. xv. (1881) pp. 88, 101. This author, however, includes in the Miocene deposits which yield a smaller proportion of extinct species than usually occurs in that system.

specific life that these changes indicate a considerable age for the High-level Reefs. Our faith, however, in that conclusion is disturbed by two facts. In the first place, it appears probable that the inclusion of the nine recent species in the Nivajé Shale is due to an intermixture of specimens from different horizons in Heneken's collection, before it was studied by Prof. Duncan. In the second place, two of the extinct species and one of the genera new to the West Indian fauna occur, not in the High-level, but in the Low-level Reefs, where they are associated with a molluscan fauna of late Pleistocene age.

Until a considerable collection of the mollusca of the High-level Reefs is available for comparison, it will not be possible to decide whether the whole of the raised limestones are Pleistocene, or whether part should be included in the Pliocene. That the latter will have to be done is most probable. The impossibility of separating the Pleistocene and the Pliocene in Tropical America has been shown by Prof. A. Heilprin[1] in the case of Yucatan, by Dr. A. C. Lawson[2] on the Western Coasts, and by M. Purves[3] in Antigua. The two systems probably merge also in Barbados.

A maximum age for the High-level Reefs is given by the fact that they overlie the beds of the Oceanic Series. The age of these is, however, still uncertain. Neither of the two fossils of any value as time-tests, that occur in them, are known elsewhere. As was remarked at the time of their description, their evidence is insufficient to enable us to do more than simply call them Upper Kainozoic.[4]

The Age of the Scotland Beds.—A lower limit to the age of the Oceanic Series' could be determined if we could settle that of the 'Scotland Beds' upon which it rests. Deposits of similar character to the latter occur in other of the Lesser Antilles and are there part of a longer series than is exposed in Barbados. The palæontological evidence, however, by which to correlate the Scotland Beds with those of neighbouring islands is meagre in the extreme. It consists of only three species of mollusca, which were described by Forbes,[5] and which were then peculiar to the island. These fossils gave no very definite evidence until Guppy[6] discovered two of them in Trinidad. He disputed the correctness of Forbes's views as to the

[1] A. Heilprin, 'Geological Researches in Yucatan,' Proc. Acad. Nat. Sci. Phil. 1891, p. 141.

[2] A. C. Lawson, 'The Post-Pliocene Diastrophism of the Coast of Southern California,' Bull. Dep. Geol. Univ. Calif. vol. i. (1893) no. 4, p. 159.

[3] J. C. Purves, 'Esquisse stratigraphique et Espèces fossiles de l'île d'Antigoa,' Ann. Soc. Malac. Belg. vol. viii. (1873) Bull. p. xxviii; also 'Esquisse géologique de l'île d'Antigoa,' Bull. Mus. Hist. Nat. Belg. vol. iii. (1884) p. 312.

[4] J. W. Gregory, '*Cystechinus crassus*, a new Species from the Radiolarian Marls of Barbados, and the evidence which it affords as to the age and origin of those deposits,' Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 647, 648; and '*Archæopneustes abruptus*, a new Genus and Species of Echinoid from the Oceanic Series in Barbados,' *ibid.* vol. xlvii. (1892) p. 168.

[5] E. Forbes in Schomburgk's 'History of Barbados,' pp. 565–567.

[6] R. J. Lechmere Guppy, 'Remarks on the Cultivation of Scientific Knowledge in Trinidad,' Proc. Sci. Assoc. Trinidad, pt. ii. (1867) pp. 81, 82; 'The Tertiary Microzoic Formations of Trinidad,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 524.

affinities of the species, which he assigned to the Lower Miocene. Guppy introduced, however, a new element of uncertainty, by separating the fossiliferous horizon from the rest of the Scotland Beds. This he did apparently only on the strength of a remark of Sir R. Schomburgk's,[1] to which he attributes greater importance than it seems to deserve. It is therefore advisable at present to correlate the whole of the beds in Barbados below the Oceanic Series with the San Fernando or Naparima Marls of Trinidad. Guppy has recently referred these (and the lower part, at least, of the Scotland Beds, goes with them) to the Eocene.[2] They are, however, now generally assigned to the Oligocene, as, for example, by Heilprin.[3] An additional argument in support of this view is now afforded by the record in an earlier part of this paper of the occurrence of two of the most typical of the West Indian Oligocene echinoids in Antigua. This tends to show that the various outcrops of shallow-water marine sediments in corresponding positions in different islands of the Lesser Antilles archipelago are all fragments of widespread Oligocene deposits. Unfortunately, the Antiguan fossil mollusca have not yet been worked out, so that we have only the evidence of the corals and the foraminifera to rely upon in the correlation of the Antiguan series. The reference of this to the Oligocene is, however, quite in accordance with the view advocated by Profs. Duncan [4] and Rupert Jones [5] in 1864; on the evidence respectively of these two groups of fossils they correlated the Antigua beds with the Lower Limestone of Malta, which is now known to be Tongrian or Lower Oligocene.[6]

As the Oceanic Series overlies the Scotland Beds it is intermediate in age between the Lower Oligocene and that of the High-level Coral Reefs. For determining its position within narrower limits we have to turn to indirect evidence.

The Age of the Oceanic Series.—The line of enquiry that at first sight promises most help is the correlation of the Oceanic Series with similar deep-sea deposits in other West Indian islands. This, however, is beset by two difficulties: the exact age of the other thalassic beds is equally uncertain, while one cannot be sure that they were all formed simultaneously. As is the case with the deep-

[1] 'Notes on West Indian Geology, with remarks on . . . Atlantis . . . and descriptions of new fossils.' . . . Geol. Mag. 1867, pp. 497, 500, fig. 5, 499.

[2] 'The Tertiary Microzoic Formations of Trinidad,' Quart. Journ. Geol. Soc. vol. xlviii. (1892) pp. 520, 521, 535, 538.

[3] A. Heilprin, 'Explorations on the West Coast of Florida and in the Okeechobee Wilderness,' Philadelphia, 1887, pp. 127, 58–59.

[4] P. M. Duncan, 'On the Correlation of the Miocene Beds of the West Indian Islands; and on the Synchronism of the Chert Formation of Antigua with the Lowest Limestone of Malta,' Geol. Mag. 1864, pp. 97–102.

[5] T. R. Jones, 'The Relationship of certain West Indian and Maltese Strata as shown by some *Orbitoides* and other Foraminifera,' Geol. Mag. 1864, pp. 102–106.

[6] J. W. Gregory, 'The Maltese Fossil Echinoidea and their Evidence on the Correlation of the Maltese Rocks,' Trans. Roy. Soc. Edinb. vol. xxxvi. (1891) pt. iii. pp. 634, 635.

sea deposits in the Mediterranean Miocenes, they may have been laid down in isolated basins formed at different times by the subsidence of various portions of the area to the required depth. A final decision upon this point cannot be arrived at until adequate collections have been made from the beds above and below the thalassic deposits, wherever these are found. So far as the evidence goes at present, it is clear that their relations to the shallow-water deposits are much the same wherever they occur, and that they occupy, at least approximatively, a corresponding position in the West Indian sequence. Thus, according to Prof. Harrison and Mr. Franks,[1] the radiolarian marls in Trinidad unconformably overlie the San Fernando or Naparima (and possibly also the Nariva Beds), just as the Oceanic Series in Barbados does the Scotland Beds. Prof. Crosby's verbal description of the position of the Baraçoa marls in Cuba shows that they are there covered by the raised coral-reefs just as are those of Barbados. In Trinidad they are either Miocene or post-Miocene; in Cuba they appear to be interstratified, or closely associated, with Miocene deposits. These Cuban beds are probably on the same horizon as the 'Pteropod Marl,' which represents the deep-sea series in Jamaica. It is generally regarded as Pliocene or even Pleistocene,[2] but this view does not rest on precise or reliable observation.

The Submergence of Panama.—There is another line of argument which affords important help. The Caribbean Sea is separated from the Pacific by a ridge in places less than 50 miles broad, and the summit of which is in one locality 154 and in another 287 feet in height. A subsidence in this region of anything like the amount that happened in Barbados would have submerged the whole isthmus, and allowed the Atlantic and Pacific faunas to intermingle. Now the evidence of the fossil mammalia of the Western States of America conclusively demonstrates that in some part of the Kainozoic period, North and South America were separated one from the other in this way. As to the date of this separation opinions differ greatly. One school of glacial geologists have seen in it a chance of explaining the cause of the refrigeration of the climate of the North Atlantic in the 'Ice Age'; for, through the channel thus formed, the warm waters piled up in the Gulf of Mexico by the main 'Equatorial Current' could pass into the Pacific, instead of flowing north as the Gulf Stream. For the diversion of the ocean-currents of the Atlantic to be of any use for this purpose, it must have happened in Pleistocene times. That date has therefore been assigned to the submergence of the Isthmus of Panama.

The evidence quoted in support of this view is twofold:—1st, the

[1] Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 218.

[2] Jukes-Browne and Harrison, *ibid.* p. 221, discuss the question and conclude that 'the final opinion of the Surveyors with respect to both these [the White Limestone and the Pteropod Marls] seems to have been that they are post-Pliocene, or in other words Pleistocene.'

direct evidence of the geology of Central America; 2ndly, the indirect evidence yielded by the faunas of the two oceans. The former rests in the main on a collection made by Dr. G. A Maack[1] during his survey of the Isthmus of Darien. It has been stated that he found numerous marine Pleistocene fossils on the very summit of the watershed. This does not, however, appear in his own account. According to this the summit of the ridge, which is crossed by the Napipi route at the height of 612 feet, is of old igneous or schistose rocks; the marine deposits on the lower slopes are Pliocene, and those at higher elevations early Tertiary. He assigns the connexion between the two seas in one passage to the Pliocene, and in another to the early Tertiary. Mr. Warren Upham first quoted Maack as proving the submergence of the isthmus to the summit of the main pass, at the height of 763 feet, in Pliocene and possibly Pleistocene times.[2] In a later note on the subject he claimed, from the work of the same observer, that a submergence of the whole isthmus had almost certainly taken place in Pleistocene time.[2] Maack's collection was said to be in Washington, where I tried in vain to find it.

It was, however, seen by Gabb in Costa Rica in 1873, and he identified in it many Miocene species. Unfortunately, it is impossible now to tell to what subdivision of the Miocene the fossils belonged. Gabb has himself collected Miocene fossils from the summit of the central ridge of Costa Rica; he describes the deposits of this age as forming the whole of the Atlantic slope, and has little doubt that they extend thence uninterruptedly to the Pacific, though he did not trace them.[3] But here again he gives no information as to what part of the Miocene the fossils indicate.

The abstract of Dr. Crawford's paper 'On the Geology of Nicaragua,'[4] issued in 1891, also gives no support to the view of the occurrence of marine Pleistocene beds above the watershed.

We must, therefore, conclude that, though there is no doubt that marine Pleistocene deposits occur at the height of 150 feet up the Atlantic slope,[5] there is not the slightest reliable geological evidence of any submergence of the isthmus in any period later than the Miocene of Gabb, and this Miocene may be Oligocene.

The Relations of the Caribbean and Panamaic Faunas.—The recent date of that event, however, has also been affirmed from a comparison of the marine faunas on either side of the isthmus.

[1] G. A. Maack, 'Reports of Exploration for a Ship Canal, Isthmus of Darien,' Public Doc. Navy Dept. no. 1144, vol. v. pp. 155–175; 'The Secret of the Strait,' Harper's New Monthly Mag. vol. xlvii. (1873) p. 812.

[2] Warren Upham, 'On the Cause of the Glacial Period,' Amer. Geol. vol. vi. (1890) p. 329; 'Pleistocene Submergence of the Isthmus of Panama,' *ibid.* p. 396.

[3] W. M. Gabb, 'Notes on Costa Rica Geology,' Amer. Journ. Sci. ser. 3, vol. ix. (1875) pp. 198–204.

[4] Rep. Brit. Assoc. 1890 (1891) pp. 812, 813.

[5] W. M. Gabb, 'Miocene Fossils in Santo Domingo,' Proc. Amer. Phil. Soc. vol. xii. (1873) p. 572.

This view has been arrived at independently by students of the mollusca, the echinoids, and the fishes. In each of these groups we find a certain well-marked resemblance between the faunas of the two sides of Central America. This may consist either in the occurrence in both of identical species, or of closely allied or equivalent species of the same genera. Thus P. P. Carpenter [1] has given a list of 35 species of mollusca which live on both coasts of Central America; of 34 species which may do so; of 41 species which are separated from those of the other side by trivial differences, and of 26 species analogous to others on the western shores. With a caution, however, which those who have quoted these figures have not always shared, Carpenter merely asked whether these facts might not imply a connexion between the two oceans across Central America in Glacial times.

Prof. A. Agassiz [2] has been no less emphatic as to the resemblances between the echinoid faunas of the two seas, and even more cautious in his conclusions. In 1869 he published a list showing that all but three of the genera of echinoidea that live on the west coast have representative species in the east-coast fauna. This list has been used by Sir Wyville Thomson [3] as a typical case of the 'law of representation,' with the natural inference that the two faunas must have had a common ancestor at no distant period. Prof. A. Agassiz has again called prominent attention to these facts in a chapter and elaborate table in his Report on the 'Blake' Echini.[4] But though these facts have been used to support the case of the recent date of the Panama submergence, as we shall see later on, Prof. Agassiz went rather to the other extreme and made it older than is necessary.

The third main group of animals that has been used to prove the recent age of the connexion is that of the fishes. It was stated that 'with scarcely any exceptions the genera are identical, and of the species found on the Pacific side nearly half have proved to be the same as those of the Atlantic.' It was therefore contended that the fishes proved 'the existence of communications between the two oceans by channels and straits which must have been open till within a recent period.'[5]

With such conclusions vouched for by such authorities, it is no wonder that those who wished to deflect the Gulf Stream in order to account for the cold of the Glacial climate felt fully at liberty to

[1] P. P. Carpenter, 'Report on the present State of our Knowledge with regard to the Mollusca of the West Coast of North America,' Rep. Brit. Assoc. for 1856 (1857), pp. 363–364.

[2] A. Agassiz, 'Preliminary Report on the Echini and Starfishes dredged in deep water between Cuba and the Florida Reef, by L. F. de Pourtalès,' Bull. Mus. Comp. Zool. vol. i. (1869) pp. 301, 302.

[3] Wyville Thomson, 'The Depths of the Sea,' London 1873, pp. 13, 14.

[4] A. Agassiz, 'Report on the Results of Dredging . . . . by the . . . . Blake,' vol. xxiv. pt. i.; 'Report on the Echini,' Mem. Mus. Comp. Zool. vol. x. (1883) no. 1, 'Origin of the West Indian (Caribbean) Echinid Fauna,' pp. 79–94.

[5] A. Günther, 'Introduction to the Study of Fishes,' 1880, p. 280, and 'The Fishes of Central America,' Trans. Zool. Soc. vol. vi. (1868) pp. 397–402.

do so. Thus Dr. A. Russel Wallace,[1] relying mainly on the evidence of the fishes, maintains that the isthmus was certainly submerged more than once in Tertiary times, and that the last separation of the two Americas in this way may have helped the oncoming of the glacial conditions. Ricketts has twice expressed[2] the views of English glacialists who accept this explanation of the cause of the 'Ice Age,' but while he admits that there is no absolute proof of the submergence of the isthmus, he urges its probability owing to the lowness of the ridge, to the 'identity' of the fauna on both sides of it, and to the great earth-movements that have taken place in this region.

Still more recently the subject has been fully discussed by Jukes-Browne and Harrison.[3] They conclude with a belief in a 'free communication between the Atlantic and Pacific at a late period in Tertiary time.' This 'late period' they distinctly refer on the same page to the Pleistocene.

Nevertheless, all recent zoological work has tended to show that though at one time the Caribbean Sea must have been in direct communication with the Pacific, this was at a very distant period, certainly prior to any part of the Pleistocene. There have always been advocates for this view. Thus Carrick Moore,[4] who has been so often quoted as showing the connexion across Panama, pointed out the great differences in the faunas of the two sides. Similarly, Belt,[5] in 1874, pointed out that the occurrence of less than 50 species common to the two faunas was really a proof that the isthmus could not have been submerged since Pliocene times; for the number is very small in proportion to the size of the faunas. Moreover, instead of P. P. Carpenter's list of species found on both sides of the isthmus having grown with further work, it has shrunk considerably. Fischer calls it 'une infime minorité (3 %),' and therefore carries back the close of the separation to the Miocene.[6]

The same change has come in the interpretation of the evidence of the fishes, thanks to the works of Jordan,[7] and of Evermann and Jenkins. By the study of much larger collections than those available to Dr. Günther, Jordan reduced the number of species common to the two faunas to 6 per cent., and declared that they were so 'substantially distinct' that no recent connexion between the seas had existed. This estimate has been still further reduced by

[1] A. R. Wallace, 'Island Life,' 2nd ed. 1892, p. 151.

[2] C. Ricketts, 'The Cause of the Glacial Period with reference to the British Isles,' Geol. Mag. 1875, pp. 573–580, and 'Some Phenomena which occurred during the Glacial Epoch,' Proc. Liverpool Geol. Soc. vol. vi. (1891) pt. iii. pp. 244–247.

[3] *Op. jam cit.* pt. ii. Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 224.

[4] J. Carrick Moore, 'On some Tertiary Beds in the Island of San Domingo, from notes by J. S. Heniker, Esq., with remarks on the Fossils,' Quart. Jo n. Geol. Soc. vol. vi. (1850) p. 43.

[5] T. Belt, 'Naturalist in Nicaragua,' 1874, pp. 263, 264.

[6] P. Fischer, 'Manuel de Conchologie,' 1887, p. 168.

[7] Dav. S. Jordan, 'A List of Fishes known from the Pacific Coast of Tropical America, from the Tropic of Cancer to Panama,' Proc. U.S. Nat. Mus. vol. viii. (1885) pp. 361–394, especially pp. 393, 394.

the work of the latter authors,[1] who described the 'fish faunæ of the two coasts as being essentially distinct'; they conclude that 'there has not been, at any comparatively recent time, any waterway through the Isthmus of Panama.' They accept the fish fauna as composed of 1307 species, and, excluding 16 species of such wide distribution that their evidence does not count, they estimate that only 4·3 per cent. are common to the two shores. They add, moreover, that they think that the mollusca yield 'even stronger evidence of the remoteness of the time when the means of communication between the two oceans could have existed.'

With the corals the evidence is still more conclusive. Two more different coral faunas than those of the West Indies and Panama could hardly be found. There is not one species common to the two. Not only so, but the genera are nearly all different. Ortmann[2] has recently published a list of genera from the two coasts to emphasize this fact. Verrill has repeatedly called attention to the almost complete difference between the two faunas, not only with species and genera, but also with families. He has summarized the results as follows:—'No species are found to be identical, while even the genera and families show remarkable contrasts. Thus the numerous genera and families of reef-building corals, so abundant on the Atlantic side, are wholly wanting on the Pacific, with the exception of *Porites*, which is represented by three or four small species. Massive Astræans, *Mœandrina*, *Diploria*, *Manicina*, *Colpophyllia*, *Agaricia*, *Siderastræa* [*Astræa*], *Oculina*, *Madrepora*, *Millepora*, are wholy unknown in the Panama fauna. But *Pocillopora*, *Montipora*, and *Pavonia*, genera unknown on the Atlantic side, are represented, the last by two gigantic species. Among the Halcyonoid Polyps we find an equal contrast, for *Eunicea*, *Plexaura*, *Plexaurella*, *Pterogorgia*, and many other very common Atlantic genera are unknown on the Pacific side, where they are replaced by numerous species of *Psammogorgia*, *Litigorgia*, and *Eugorgia*, which are eminently characteristic of that coast.'[3] Elsewhere he concludes 'that there has been no connexion [between the oceans], or at least none sufficient to materially change the course of the Gulf Stream, since the commencement of the Tertiary period.'[4]

We may, therefore, conclude from the evidence of the recent

[1] B. W. Evermann and O. P. Jenkins, 'Report upon a Collection of Fishes made at Guaymas, Sonora, Mexico, with Descriptions of New Species,' Proc. U.S. Nat. Mus. vol. xiv. (1891) no. 846, p. 126.

[2] A. Ortmann, 'Beobachtungen an Steinkorallen von der Südküste Ceylons,' Zool. Jahrb. Bd. iv. Abt. f. Syst. (1889) p. 528.

[3] A. E. Verrill, 'On the Comparison of the Coral Faunæ of the Atlantic and Pacific coasts of the Isthmus of Darien, as bearing on the supposed Former Connexion between the two Oceans,' Amer. Nat. vol. iii. (1869) p. 500.

[4] A. E. Verrill, 'On the Polyps and Corals of Panama, with Descriptions of New Species,' Proc. Boston Soc. Nat. Hist. vol. x. (1866) p. 325. See also his 'Comparison of the Tropical Faunæ of the East and West Coasts of America,' in 'Notes on Radiata, No. 3,' Trans. Connect. Acad. vol. i. pt. ii. (1867) pp. 339, 340.

fishes, mollusca, corals, and echinoids that there has been no waterway across the isthmus in Pleistocene times, for this must have been closed prior to the development of the existing species. No doubt the physical conditions of the two seas are somewhat different, and hence variation may have gone on at an unusually rapid rate. Nevertheless, the connexion between the two seas cannot have lasted after the close of the Miocene. The two Agassiz, father and son, have proposed to date it much farther back than this. They referred the separation of the two oceans and the formation of the Gulf Stream to the period at the close of the Cretaceous.[1] As Prof. A. Agassiz stated it in 1883, 'soon after the end of the Cretaceous period, the separation of the great Atlantic and Indo-Pacific marine realms began.'[2] This is, however, probably considerably too early, as that author admits in a letter published by Jukes-Browne and Harrison.[3] As we have already seen, the stratigraphical evidence advanced by Gabb and Belt renders a Miocene submergence highly probable, although the operations for the Panama Canal did not lead to the discovery of any Kainozoic deposits on the summit of the pass chosen for it. According to Dr. Dall—whose recently expressed opinion on this subject[4] carries the greatest weight—the Kainozoic rocks of the higher levels are all either Miocene or Eocene, while the summit of the ridge is formed of 'Azoic' rocks of uncertain age.

The Connexion of North and South America.—The comparison of the faunas, though conclusively proving the former connexion and long-distant separation of the two oceans, does not, however, enable us to fix the date of these events with much precision: for we do not know the rate at which the faunas have varied. In order to restrict the date within narrower limits we must turn to the migrations of the land-fauna, and especially to the evidence of the fossil mammalia of the Western States. This has recently been considered by Prof. W. B. Scott,[5] who points out the occurrence of a glyptodont (*Caryoderma*) of a South American type in the Loup Fork Beds. These must accordingly be later than the connexion between the two Americas. Prof. Scott therefore admits that, if the view of Dall and Harris that this was not established till the end of the Miocene

[1] Louis Agassiz, Report upon Deep-Sea Dredgings in the Gulf Stream during the third Cruise of the U.S. Steamer 'Bibb,' Bull. Mus. Comp. Zool. Harvard, vol. i. (1869) p. 377; Alex. Agassiz, 'Preliminary Report on the Echini and Starfishes dredged in deep water between Cuba and the Florida Reef, by L. F. de Pourtalès,' Bull. Mus. Comp. Zool. Harvard, vol. i. (1869) p. 305; and 'Three Cruises of the "Blake,"' *ibid.* vol. xiv. 1888, p. 116.

[2] Alexander Agassiz, Reports on the Results of Dredging . . . . by the 'Blake,' no. xxiv. pt. 1; 'Report on the Echini,' Mem. Mus. Comp. Zool. Harvard, vol. x. no. 1 (1883), p. 83.

[3] *Op. jam cit.* pt. ii. Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 223.

[4] W. H. Dall and G. D. Harris, 'Correlation Papers: Neocene,' Bull. U.S. Geol. Surv. no. 84 (1892), p. 151.

[5] W. B. Scott, 'The Mammalia of the Deep River Beds,' Trans. Amer. Phil. Soc. vol. xvii. (1894) p. 62.

be correct, then the Loup Fork Beds must be Pliocene. Its fauna however, has such Miocene affinities that Scott suggests that the isthmus must have emerged before the end of this period. There does not seem to be any reliable evidence to put against that of the Loup Fork mammalia. Neither Gabb nor Dall have recorded the names of the Miocene species from the higher levels of Panama, nor did they state what division of the Miocene the fossils indicated.

It is therefore probable that the waterway across Central America was finally closed in the Lower Miocene, or possibly even in the Upper Oligocene.

The Date of '*Antillia*.'—A further complication remains to be considered. It is not at all certain that when the Isthmus of Panama was submerged there was a free communication between the Atlantic and the Pacific Oceans. The Caribbean Sea may then have been a gulf from the Pacific, separated from the Atlantic by the land area of the hypothetical 'Antillia.' That there was once a connexion between North and South America along the chain of the Windward Islands, Cuba, the Bahamas, and Florida is not improbable. Evidence for this, either in whole or part, has been advanced by De Castro, Cope, Leidy, and others, whose arguments have recently been well summarized by Sir Henry Howorth.[1] Further evidence could be adduced from the study of the land-shells,[2] and also from the remarkable distribution of the species or varieties—whichever they be—of *Peripatus*. That Cuba was once connected with Yucatan and Florida is almost certain: that this connexion was in existence in the Pliocene, and probably also in the Pleistocene, is shown by the evidence collected by De Castro.[3] That the area of the Windward Islands was occupied by land in the Lower Kainozoic is also most probable. But this was all submerged at the period when the Oceanic Deposits of Barbados were laid down. There is no adequate evidence to show that at any time after this was there more land in this region than there is at present. The evidence of the *Archæopneustes*-limestone which overlies the Oceanic Deposits, and of the series of raised reefs, tends to show that Barbados has been undergoing a long, steady upheaval since the period of the great submergence. The rarity of mammals on these islands shows that they have not been part of a continuous tract of land since they rose above the sea: as contended by Prof. A. Agassiz,[4] the islands probably have always been isolated, and

[1] 'The Mammoth and the Flood,' 1887, pp. 360–366.

[2] Thomas Bland, 'On the Geographical Distribution of the Genera and Species of Land Shells of the West Indian Islands: with a Catalogue of the Species of each Island,' Ann. Lyc. Nat. Hist. New York, vol. vii. (1862) pp. 335–361; 'Additional Notes on the Geographical Distribution of Land Shells in the West Indies,' *ibid.* vol. ix. (1870) pp. 238–241.

[3] M. F. de Castro, 'Pruebas Paleontológicas de que la Isla de Cuba ha estado unida al continente Americano, y breve idea de su constitucion geológica,' Bol. Com. Mapa geol. España, vol. viii. (1881) pp. 357–372.

[4] A. Agassiz, 'Three Cruises of the "Blake",' Bull. Mus. Comp. Zool. Harvard, vol. xiv. (1888) p. 116.

have received their inhabitants in the same manner as true oceanic islets.

Affinities of the Fossil Coral Fauna.—One final argument against the view of the Pleistocene connexion between the Caribbean Sea and the Pacific is afforded by the evidence of the fossil corals of Barbados. When we remember that the High-level Reefs there contain two genera now extinct in the West Indies, and that the stratigraphical evidence indicates that the reefs have been gradually formed during a long, slow elevation, it is difficult to doubt that the oldest reefs must date back at least to early Pleistocene times. Nevertheless the coral fauna of the High-level Reefs does not present the slightest trace of any intermixture with Pacific types. In fact the forms found fossil in, but not known to be still living around, Barbados increase the differences between the Caribbean and Panamaic faunas. They strengthen the resemblance of the former to that of the Red Sea and Indian Ocean, and to the fossils of the Mediterranean basin. One cannot compare the West Indian corals with those of such deposits as the Miocene of the hills around Turin, or with those which are still living in the Red Sea, without recognizing that they are part of the same fauna.

The remarkable resemblances between the present fauna of the West Indian seas and that of the Miocene deposits of the Mediterranean basin have frequently been pointed out. Michelotti [1] identified many of the fossils from the hills of Turin with recent West-Indian species. Duncan [2] determined the presence of the same species of corals in the rocks of Antigua and Malta. Pourtalès [3] suggested that the Tertiary deep-sea fauna of Europe migrated westward and supplanted that of the West Indies. Cleve [4] and Guppy,[5] on the evidence of the mollusca, pointed out that the affinities of the West Indian Miocene faunas are with those of Europe instead of North America, and therefore conclude that they reached that region by migration across the Atlantic. The echinoidea yield similar and more conclusive evidence. As I have previously pointed out,[6] the intimate affinity between those of the

[1] J. Michelotti, 'Specimen Zoophytologiæ diluvianæ,' Turin, 1838. Though most of the living West Indian genera of corals are represented by equivalent species in the North Italian Miocenes, I am not persuaded of the specific identity of the two series. Michelotti's records are therefore not included in the synonymy.

[2] P. M. Duncan, Geol. Mag. 1864, pp. 97–102.

[3] L. F. de Pourtalès, 'Zoological Results of the Hassler Expedition, Crinoids and Corals,' Ill. Cat. Mus. Comp. Zool. Harvard, no. viii. (1874) p. 49.

[4] P. T. Cleve, 'On the Geology of the North-Eastern West India Islands,' Handl. k. Svensk. Vet.-Akad. vol. ix. no. 12 (1871) p. 48.

[5] R. J. L. Guppy, 'On the Tertiary Mollusca of Jamaica,' Quart. Journ. Geol. Soc. vol. xxii. (1866) p. 285; 'On the Relations of the Tertiary Formations of the West Indies,' *ibid.* pp. 584–590; 'Notes on West Indian Geology, with Remarks on the Existence of an Atlantis in the Early Tertiary Period, and Descriptions of some New Fossils from the Caribbean Miocene,' Geol. Mag. 1867, pp. 496–501; 'On some New Tertiary Fossils from Jamaica,' Proc. Sci. Assoc. Trinidad, pt. x. vol. ii. (1873) p. 72.

[6] J. W. Gregory, 'The Relations of the American and European Echinoid Faunas,' Bull. Geol. Soc. Amer. vol. iii. (1891) pp. 101–108.

West Indies and the Mediterranean can only be explained by the assumption of the existence of a shallow-water connexion across the Central Atlantic in—at latest—Miocene times. That the fauna did not follow along the shores of the North Atlantic basin is shown by its absence from the northern Miocenes of Europe and America. The evidence now adduced from the fossil corals of Barbados lends support to this view, as showing that the West Indian fauna is only a fragment of that of the Mediterranean Miocene, and has received nothing from the Pacific. This is in full agreement with Prof. Suess's theory that the Atlantic is of comparatively recent geological age, and arose by the gradual enlargement of two great bays which run north and south from a sea that once extended across the mid-Atlantic from Europe to America, including both the Mediterranean and the Caribbean seas.

The Permanence of Oceans and Continents.—The geological history of the West Indian area is therefore strongly opposed to the theory of the permanence of the great continental masses and of the ocean-basins. For, while on the one hand it supplies us with an example of the elevation of true abyssal oozes to the height of 1095 feet above the sea, on the other the origin of its shallow-water fauna can only be explained by the formation of the basin of the Central Atlantic in Middle Kainozoic times. It has been objected that the discovery of true deep-sea oozes in Barbados did not really seriously affect the question, as these occurred only on the extreme margin of a volcanic area, where great earth-movements were most likely to have taken place. The discovery, however, of exactly the same deposits in Cuba shows that this argument is invalid, as they there occur in the very centre of the West Indies. The submergence was therefore probably regional in extent, though it is possible that these two sets of oozes may have been formed in isolated areas of depression. It is not improbable that the subsidence which led to the deposition of the Oceanic Series of the West Indies was one of the earth-movements which, in Langhian or Helvetian (Lower or Middle Miocene) times, broke up the great Antilleo-Mediterranean Sea, by the formation across it of the main trough of the Atlantic. That the deep-sea oozes were subsequently raised in Barbados to a great height above the sea is doubtless due to the position of that island on the line connecting the eastern coasts of North and South America. The remarkable amplitude of the oscillations of level along this is not surprising, whether we simply regard it as one of the primitive lines of weakness in the crust of the earth, or, with Prof. Lapworth, explain its instability by its coincidence with a septum of the Atlantic fold.

VII. Summary of Conclusions.

A. *Correlation of the Barbados Sequence.*

Raised Coral Reefs.	Low Level	Pleistocene.
	High Level	Pliocene.
Oceanic Series.		Miocene (and possibly partly Pliocene and partly Oligocene).
Scotland Beds.		Oligocene (probably Lower).

B. *History of the Caribbean Area in Kainozoic Times.*

1. In Eocene times the site of the Windward Islands was a land-area. There is no adequate evidence of the existence of this land in post-Tongrian (that is, post-Lower Oligocene) times.
2. North and South America were then separated by a waterway across the Isthmus of Darien, and probably also across much of the States of Costa Rica and Nicaragua.
3. In early Miocene, or possibly Oligocene, times the two oceans were separated by the final emergence of Central America and its union with a continuous land-area.
4. There is no evidence, afforded either by stratigraphy or zoology, to show that the Atlantic and Pacific Oceans have been united across Central America in post-Miocene times.
5. Approximatively simultaneous with the rise of the west of the Caribbean Sea, subsidence was taking place to the east. This plunged part of the area, now occupied by land, into abyssal depths. True deep-sea oozes were then deposited in Barbados, Trinidad, and Cuba.
6. In some part of the late Miocene or Pliocene epoch re-elevation began. Deposits characteristic of shallower conditions (the *Archæopneustes abruptus*-limestones) were formed: these contain simple corals which, though too imperfect for description, indicate a depth of between 100 and 300 fathoms.
7. In Pliocene or early Pleistocene times (probably the former) the continued elevation of the Barbados area brought it within the zone of reef-coral growths. The first reefs formed were the High-level Reefs, now raised nearly 1000 feet above the sea. From these a continuous series forms a cap to the island, and extends down to reefs of late Pleistocene age at sea-level.

Synonymy of Corals.

1. The types of the numerous species founded by Duchassaing & Michelotti have been examined. Thirty-three are now placed as synonyms.
2. The following species, described as being from the West Indian Miocene, are reduced to the rank of synonyms. They have been founded on Pleistocene specimens, probably included by accident among the Miocene fossils:—

Stephanocœnia dendroidea, Dunc., p. 258.
Antillia bilobata, Dunc., p. 260.
Dichocœnia tuberosa, Dunc., p. 268.
Barysmilia intermedia, Dunc., p. 269.
Astræa endothecata, Dunc., p. 271.
—— *cylindrica*, Dunc., p. 271.
Astræa barbadensis, Dunc., p. 272.
Heliastræa altissima, Dunc., p. 272.
Antillastræa spongiformis, Dunc., p. 276.
Siderastræa grandis, Dunc., p. 279.
—— *crenulata*, var. *Antillarum*; Dunc., p. 279.

3. The genus *Antillastræa* is regarded as a synonym of *Stephanocœnia*, and *Mycedium* of *Agaricia*. *Antillia* is also abandoned, as the epitheca is not regarded as a reliable diagnostic character in the Astræidæ simplices.
4. The genera *Hydnophora* and *Echinopora* are added to the West Indian fauna.

Affinities of the Fossil Corals.

1. Those of the raised reefs of Barbados give no trace of the influence of admixture with Pacific types.
2. The fauna is an offshoot of that of the Miocene of the Mediterranean basin.
3. Its nearest living ally is, therefore, that of the Red Sea and Indian Ocean.
4. The migration of this fauna westward across the tropical Atlantic supports the theory of the existence of a shallow-water ridge or coast-line across that ocean in Middle Kainozoic times. For the corals could not have crossed the cold abysses of the Atlantic, and, as they are absent from the Miocene deposits of Northern Europe and the United States, it is clear that they did not work their way around the shallow waters of the North Atlantic. As some echinoidea of similar range, which have no free-swimming larval stage, must have crossed at the same time, it is not probable that the fauna reached the West Indies by larvæ floating across the ocean.

The Theory of the Permanence of the Ocean-Basins.

1. The evidence of the geology and palæontology of the West Indies is therefore opposed to the theory of the permanence of the ocean-basins. For, on the one hand, it supplies a case of abyssal deposits raised more than 1000 feet above the sea: on the other, the origin of the faunas can only be explained by the subsidence of part of the Mid-Atlantic in Miocene times.
2. The occurrence of radiolarian oozes in Cuba shows that the submergence did not affect only the margin of the West Indian area. The great subsidence was probably part of that which formed the basin of the Mid-Atlantic.

Note on Additional Mollusca from the Scotland Beds.—I have received this morning (18th Feb.) from Mr. Jukes-Browne a small collection of mollusca from the Scotland Beds. They are too fragmentary for full determination, but so far as the evidence

which they furnish goes it is strongly in favour of the Oligocene age of the deposits. The fossils are as follows :—

Entaliopsis? aff. *rudis* (Gabb).
Cuphus aff. *incrassatus*, Gabb.
Cardita aff. *scabricostata*, Guppy.
Ostrea, sp.
Lampusia (= *Triton*), sp.

The best-preserved fossil has been kindly identified by Mr. G. F. Harris as a very close ally of *Surcula transversaria* (Lam.). This is a common Oligocene species; it occurs, for example, at Brockenhurst, and ranges down to the Middle Eocene. Mr. Harris states that the general aspect of the fossils resembles that of the Brockenhurst Beds and their equivalents in the Paris Basin.

Mr. R. B. Newton has kindly determined three mollusca from the Scotland Beds collected by Mr. Jukes-Browne. They are *allied* to

Clavilithes longævus (Sol.).
Neritina aperta, J. de C. Sow.
Potamides funatus, G. Sow.

Mr. R. B. Newton says that these 'are probably of Lower Oligocene age (Headon Beds).'

EXPLANATION OF PLATE XI.

Fig. 1. *Hydnophora latefundata*, sp. n.; High-level Reefs, Castle Grant. Fig. 1 *a*. Specimen, nat. size (R 2460). Fig. 1 *b*. Monticules of the same, × 4 diam.

Figs. 2 & 3. *Echinopora Franksi*, sp. n.; Low-level Reefs, Barbados. Fig. 2 *a*. Coral (R 2514), reduced to $\frac{1}{3}$. Fig. 2 *b*. Corallites from a flat area on the same specimen, × 3 diam. Fig. 2 *c*. Corallites from a boss on the same specimen, × 3 diam. Fig. 3. Section of a corallite, × 7 diam.

Figs. 4 *a* & 4 *b*. *Solenastræa stellulata* (Ell. & Sol.); High-level Reefs, Castle Grant. Two types of calyces from different parts of the same specimen (R 2469), × 3 diam.

Figs. 5 & 6. *Stephanocœnia intersepta* (Esper); Low-level Reefs, Barbados. Fig. 5 *a*. The normal type of corallites, ×4 diam. Fig. 5 *b*. Corallites, scattered and rounded, from the same specimen (R 2533), × 4 diam. Fig. 6. Corallites of the *Michelini*-type from another specimen (R 2195), × 4 diam.

Fig. 7. *Agaricia agaricites* (Pallas); Low-level Reefs, Barbados. Two figures of different parts of a funnel-shaped specimen (R 2482), × 3 diam. Fig. 7 *a* shows the *Agaricia* and 7 *b* the *Mycedium* condition.

Discussion.

The President alluded to the interest which the Fellows of the Society had for many years past taken in the geology of the West Indian area. He cited the papers published in the Geological Society's Journal by old West Indian workers such as De la Beche, R. Lechmere Guppy, Sawkins, Wall, Lucas Barrett, while our past President, Prof. P. Martin Duncan, had done much in the study of the corals; then, too, we had papers by Harrison, Jukes-Browne, Agassiz, and more than twenty other workers, who had laboured in this field of enquiry. Dr. Gregory had added new points of interest to the geology of this area, and in his paper had dealt

with three series of deposits—the Reefs, the Oceanic Series, and the Scotland Beds—which owe their origin to varying age and very different depth of deposits.

Mr. Marr, having obtained the President's permission, read the following remarks made by Mr. Jukes-Browne (who was prevented by ill-health from being present at the meeting):—

'As Dr. Gregory's paper deals with the relative ages of the rocks in Barbados, I take the opportunity of communicating the results of some investigations made by Mr. G. F. Franks, F.G.S., in the neighbourhood of Bissex Hill. In the paper by Prof. Harrison and myself, we stated that the higher part of this hill consisted of granular *Globigerina*-marl capped by a limestone and marl containing foraminifera, shell-fragments, and included pieces of chalk. This we regarded as a separate formation, but classed the marl below with the Oceanic deposits. Mr. Franks, however, has discovered detrital limestones in the *Globigerina*-marls, as well as some evidence which suggests that the whole mass of *Globigerina*-rock lies unconformably upon the Oceanic Series, and is faulted down into the centre of the Bissex Hill area.

'Mr. Franks has not yet been able to find a clear and unfaulted junction of the two formations, but, if his observations are correct, the group of beds which we classed as of intermediate date between the Oceanic Series and the Coral Rocks acquires a greater importance. Moreover, it seems to be more intimately connected with the Coral Reefs than with the Oceanic deposits, for Mr. Franks has found patches of reef-rock on the spurs of the hill, which seem to pass down into the upper shelly portion of the Foraminiferal Marls. He has also discovered the same succession in a well-shaft at Bowmanston.

'In view of these facts, we are quite prepared to accept Dr. Gregory's conclusion that the Oceanic Series is of Miocene age, the more so as Dr. Spencer has come to the same conclusion with respect to the Radiolarian Earths of Cuba, after a personal study of the geology of that island. The Barbadian succession may therefore be provisionally stated as follows, and I hope that ere long I may be able to lay the evidence for it before the Society:—

Pleistocene and Pliocene.	{	Low-level Reefs. High-level Reefs. Foraminiferal Marls and Limestones.
		Break.
Miocene	=	Oceanic Series.
		Break.
Eocene	=	Scotland Beds.'

Mr. Clement Reid observed that, judging by the extent of post-Oligocene denudation in Europe, it is unsafe to take the present height of the Isthmus of Panama as any measure of its height in Tertiary times. If the mountains were formerly much higher, it is evident that great elevations and depressions might take place in

the West Indies without connecting the Atlantic and Pacific Oceans.

Mr. G. F. Harris remarked that this was a valuable contribution to our knowledge of the palæontology and physical geology of the West Indies. With reference to the few mollusca obtained from the Scotland Beds, he believed that they were of Lower Oligocene age, *Surcula belgica* being very characteristic of that horizon in Europe. The *Clavilithes* exhibited was, however, very similar to the stunted forms of *C. deformis* from the upper part of the Sables Moyens of the Paris Basin—a bed of Upper Eocene age. In addition to the Tertiary fossils from Panama alluded to by the Author, Dr. Dall of Washington had described *Glyptostyla panamensis* and several other mollusca given to him by Prof. Alex. Agassiz, and obtained along the line of the canal 12 miles south of Colon (at Vamos-Vamos) a few feet above the sea-level. These seemed to indicate the presence, in the Isthmus, of beds equivalent in age to the Martinez group of California, which was now merged in the Chico-Téjon —partly Eocene and partly Upper Cretaceous. The fossils referred to presented an Eocene facies. He quite agreed with the Author, but on different grounds, that there had been no land-connexion between Florida and South America by way of the larger islands, to form the supposed 'Antillean continent,' in recent Tertiary times. The distribution of the land-mollusca of Cuba, Hayti, Jamaica, Barbados, and Trinidad, amongst other islands, was directly opposed to such an hypothesis, each island possessing a number of forms peculiar to it and unlike those on the mainland. It was hard to believe that such marked differentiation could have resulted since Pliocene times as had been assumed by certain American writers. He thought it much more reasonable to suppose, with the Author, that the land-connexion had taken place at an earlier period.

The Author remarked that he had been much interested by Mr. Jukes-Browne's contribution to the Discussion, as Mr. Franks's observations confirmed the conclusion expressed at the end of his paper on *Archæopneustes* in 1892. He read the passage maintaining that the nodular limestones were formed on the rising dome of the deep-sea deposits, and were intermediate in age between these and the Coral Limestones. They would therefore be unconformable to the Radiolarian Marls. He preferred at present to call the Scotland Beds Lower Oligocene. He quite agreed with Mr. Reid that the Panama ridge was at one time higher; but this argument was not a valid reply to those who maintained the Pleistocene age of its elevation. He was glad Mr. Harris thought that the land-mollusca (the evidence of which is considered in the paper) opposed Dr. Spencer's views as to the recent existence of the continent of Antillia. He thought that the evidence of the faunas of the Windward Islands was conclusive against their ever having formed part of a great continent since their emergence from the sea.

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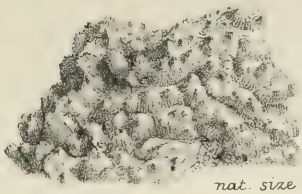
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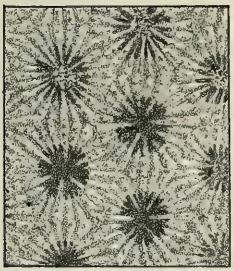
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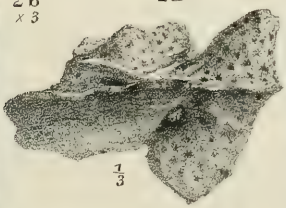
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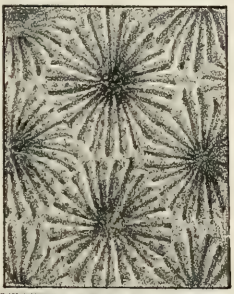
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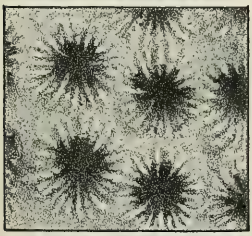
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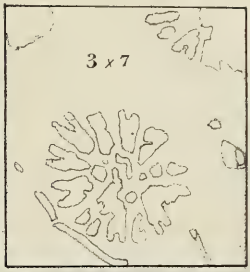
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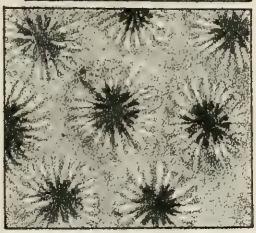
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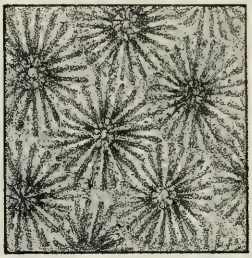

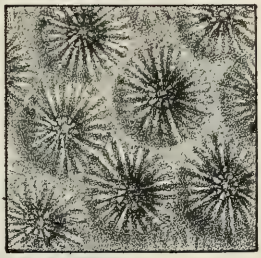

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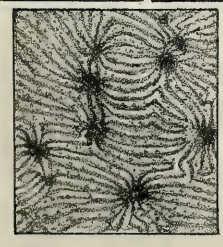
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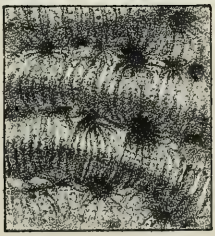
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FOSSIL CORALS FROM BARBADOS.

23. Notes *on the* Chemical Composition *of some* Oceanic Deposits.

By Prof. J. B. Harrison, M.A., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read March 6th, 1895.)

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I. Introduction.

When describing in this Journal the raised and consolidated deep-sea oozes which occur in the island of Barbados, we experienced great difficulty in comparing our analyses of these deposits with those made by Dr. Brazier of the corresponding recent oozes. This was especially the case with the 'red clays' and, in a less degree, with the other deposits. In the paper above referred to [1] we remarked that 'if the Challenger samples of red clay which contained only small amounts of calcium carbonate and the samples of the Barbados argillaceous earths had been analysed by similar methods, a close resemblance in composition would have been found in them; and the differences would have been such only as would arise from the action of percolating water containing organic acids upon the Barbados deposits, from which the calcium carbonate and the iron peroxide present in a limonitic form would be leached out.'

We know that the analyses published in the 'Challenger' Report on Deep-Sea Deposits were made before Dr. Murray was placed in charge of the 'Challenger' Office and that he was fully aware of their shortcomings, as testified by his discussions of them in different parts of the Report. It is especially to be regretted that the analyses of the 'red clays' were not made on a more satisfactory plan, for the method employed by Dr. Brazier was not calculated to bring out the real mineralogical composition of these deposits.

Dr. Murray very kindly placed at our disposal a typical sample of 'red clay' and three samples of *Globigerina*-ooze, all of them in sufficient bulk for satisfactory analysis. These have been carefully analysed by the same methods as those that were employed in the case of the Barbadian deposits.

With respect to the *Globigerina*-oozes, we find that the inaccuracies resulting from Dr. Brazier's methods are at a minimum in the case of those which have more than 80 per cent. of calcium carbonate, but even in these the amount of soluble silica is too high, and the 'loss on ignition' is unaccountably high; while in the less calcareous

[1] Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 191.

oozes the errors would approach those discoverable in the analyses of the 'red clays.'

The analyses which follow were made by one of us in the Government Laboratory of British Guiana, with the collaboration of Mr. John Williams, F.C.S., the Assistant Government Chemist. The results have been considered by both of us, and the paper has been finally written out by the author resident in England. In order to secure really useful and accurate results much tedious laboratory work is required, and moreover each analysis has been checked by repetition. In this work, and also in the arrangement of the results, Mr. J. Williams has afforded us very considerable assistance, for which our thanks are due to him.

Some detailed analyses of English Chalks have also been made in the same way, for comparison with those of the Barbadian Chalks and the recent *Globigerina*-oozes.

We propose to deal first with the 'red clay,' comparing it with the coloured earth of Barbados, and thereafter to discuss the calcareous oozes and their more ancient prototypes.

II. Analysis of Red Clay.

This material was a red clay obtained from Station 256 in the Pacific, lat. 30° 22′ N. and long. 154° 56′ W., at a depth of 2950 fathoms. Our sample was analysed in the way usually employed for clays, but the soluble silica present was determined in the manner described in our paper on the Oceanic Deposits of Barbados.[1] The alkalies were separately determined. The material was also tested for the existence of crystalline quartz by the method indicated in that paper, and as the amount found was only just appreciable (·01 per cent.), the silica in the siliceous residue left after boiling with sulphuric acid and fusing with microcosmic salt is entirely combined silica.

But even when we have separated the quartz and colloid silica, we do not gain much information by merely setting down the amounts of silica, alumina, etc. in the residue. In these deep-sea clays some of the material is evidently a clay in a state of very fine division, but the high percentage of silica shown by ordinary analysis is sufficient to indicate the presence of some other substance.

[Having reason to believe that this substance was disintegrated pumice, we separated it in the following way :—A portion of the clay was boiled repeatedly with strong sulphuric acid (about 94 parts H_2SO_4 and 6 of water), which has the power of decomposing clay and the decomposition-products of volcanic rocks, but is practically without action on a glassy pumice. The residue from this treatment was then digested with hydrochloric acid, in order to dissolve out any basic sulphates which might have been formed; and the remaining insoluble residue was boiled with a solution of caustic potash, in order to remove the soluble silica set free by the acid treatment. This process is, in fact, the same as that used by Dittmar in his prepara-

[1] Quart. Journ Geol. Soc. vol. xlviii. (1892) p. 183.

tion of the 'purified pumice,' of which an analysis is given in the 'Challenger' volume.[1]—April, 1895.]

The material so separated has the aspect of fine pumiceous sand, and the analysis of it corresponds with that of acidic pumice, though the proportions of soda and potash are unusually large. As a matter of fact, fragments of acidic pumice were actually found in the mass of the deposit brought up by the dredge at this locality, as well as in many other dredgings of red clay.[2]

Besides the ordinary organic and inorganic constituents we find that all the dried oceanic deposits contain a certain proportion of chlorides of sodium and magnesium, together with a smaller amount of calcium sulphate. The presence of these salts is doubtless due to the evaporation of the sea-water with which the ooze was saturated when brought up from the ocean-bottom. Consequently, in grouping the results of an analysis of dried ooze another class of constituents must be admitted, namely, that of adherent sea-salts.[3]

We think, therefore, that the ingredients of a red clay should be arranged under four heads:—

1. Argillaceous constituents.
2. Pumiceous matter.
3. Organic constituents.
4. Adherent sea-salts.

Arranged in this way, the result of our analysis of the material, dried at 212° F., is as follows:—

1. *Argillaceous Constituents.*	
Loss on ignition	6·32
Alumina	12·13
Peroxide of iron	10·39
Peroxide of manganese	1·56
Lime	0·69
Magnesia	0·56
Potash	0·92
Soda	1·58
Silica (combined)	33·70
	67·85
2. *Pumiceous Matter.*	
Alumina	3·58
Peroxide of iron	0·16
Lime	0·32
Magnesia	0·82
Potash	0·96
Soda	1·64
Silica (combined)	15·78
	23·26
3. *Organic Constituents.*	
Colloid silica	4·61
Calcium carbonate	0·92
Calcium phosphate	trace.
Nitrogenous organic matter	0·35
	5·88
4. *Adherent Sea-salts.*	
Sodium chloride	1·84
Magnesium chloride	0·96
Calcium sulphate	0·80
5. Quartz	0·01
	3·61
Total	100·60

For comparison with the above we append the analysis of part of the same dredging made by Dr. Brazier, and tabulated in the 'Chal-

[1] 'Challenger' Report on Deep-Sea Deposits, 1891, p. 457.
[2] *Ibid.* p. 297.
[3] For the suggestion which led us to recognize this point we are indebted to Mr. J. Williams.

lenger' Report on Deep-Sea Deposits, p. 430. The material was dried at 230° F. :—

Loss on ignition		4·50
Portion soluble in hydrochloric acid =45·32.	Alumina	6·00
	Ferric oxide	9·77
	Calcium phosphate	0·48
	Manganese oxide	0·68
	Calcium sulphate	0·42
	Calcium carbonate	1·69
	Magnesium carbonate	1·33
	Silica	24·95
Portion insoluble in hydrochloric acid=50·18.	Alumina	11·37
	Ferric oxide	2·00
	Lime	1·14
	Magnesia	0·85
	Silica	34·82
		100·00

It will be seen that this analysis gives no real indication of the mineralogical composition of the clay. This is owing to the method employed, which is stated by Dr. Brazier himself to be as follows [1]:—

'The deposits in these analyses were treated as earths by me, and, after digestion in hydrochloric acid, were evaporated to dryness and subsequently re-dissolved as far as possible; the insoluble residue, after weighing, was treated with boiling caustic potash, and so much of the residue as was then dissolved was looked upon as silica of easy combination, and classed along with the bodies soluble originally in hydrochloric acid.'

It is difficult to see what object was gained by this proceeding, or why silica only soluble in boiling caustic potash should be classed as 'soluble in hydrochloric acid,' as it is in all the printed analyses. In order to ascertain for ourselves what the effect of digestion in hydrochloric acid would be, we digested 5 grams of the 'red clay' with 10 per cent. hydrochloric acid over the water-bath for 12 hours, and then found that we had 16·93 per cent. of silica soluble in alkalies. Next we boiled a like amount of clay with strong hydrochloric acid as long as the acid attacked the clay, and we then had 26·22 per cent. of silica soluble in alkalies. As Dr. Brazier made 24·95 per cent. of silica soluble, it may be assumed that he digested the material with strong hydrochloric acid for a similar length of time. The result was simply to decompose a larger portion of the silicates and to mask the actual amount of soluble organic or colloid silica present. It will be seen from our analysis that the amount of this colloid silica, derived from radiolaria, diatoms, and sponge-spicules, is only 4·61 per cent.

The next point to be noticed is that the alkalies were not determined by Dr. Brazier, but in the published analyses are either included under the head of 'insoluble silica' or else with some other constituent, the amount of which was determined by difference, but is not indicated. In our detailed analyses we found the total amount

[1] Quoted by Dr. Murray, 'Challenger' Report on Deep-Sea Deposits, p. 29.

of alkalies present to be 6·07 per cent., whilst a separate determination of them made for the purpose of control by the Lawrence Smith method gave 6·17 per cent., and we therefore consider that the omission of this determination is a matter of considerable importance.

The chlorine also was not estimated, and in consequence the presence of sodium and magnesium chlorides was not detected, the amount of magnesia really present in a soluble form being included among that calculated as carbonate.

With regard to the alumina, Dr. Murray says ('Challenger' Report on the Deep-Sea Deposits, p. 199):—'After such a treatment [as that adopted by Dr. Brazier] the clayey matter should pass entirely into solution, and to estimate the quantity of this substance we have merely to take account of the data given in the columns showing the substances soluble in hydrochloric acid. It must be remembered, however, that a certain part of the alumina indicated in the soluble portion does not exist as argillaceous matter in the deposit, but comes from the action of the acid and caustic potash upon the aluminous silicates and rocks present in the Red Clay.'

In this Dr. Murray appears to be mistaken; the alumina rendered soluble by Dr. Brazier's method (6 per cent.), and derived from both sources, is only half as much as we find to exist as argillaceous matter set free from the aluminous silicates by the action of sulphuric acid.

The fact is that Dr. Brazier's analyses of Red Clay do not afford any reliable basis for discussing the mineralogical constituents of the deposit.

To return to the analysis which we now publish, and in making which it has been our object to isolate the argillaceous matter as completely as possible, we are aware that our estimate of it as forming 67·85 per cent. of the deposit must include all the minute crystals of phillipsite which Dr. Murray says are always scattered through the Red Clay; but, as Dr. Murray believes these to be actually in process of formation out of the argillaceous constituent of the clay by the chemical action of the sea-water, we think the inclusion of these minute crystals is not a matter of much importance; for, if it were not for the action of the sea-water, the constituent elements of these crystals would not have been separated out of the clay.

With regard to the nature of this argillaceous ingredient, it is evidently a more highly silicated compound than a pure clay or hydrated ortho-silicate of alumina; for, if the substance were only a mixture of ordinary hydrated silicate of alumina and free hydrated peroxide of iron, the proportions of silica and alumina would be as 14 to 12, whereas they are actually as 33 to 12.

If, however, we calculate the percentage composition of this argillaceous matter, we can compare it with other known substances. When this is done, it is seen to bear a strong resemblance to the ferruginous clays and earths which are the product of the decomposition of certain basic igneous rocks, and especially to the palagonites derived from basic volcanic glass.

On consulting Dr. Murray's volume we found that, as a matter of fact, minute fragments of volcanic glass and palagonite were found in this particular Red Clay, as well as several pieces of pumice, 'one of which was red in colour and appeared to be undergoing alteration' (*op. cit.* p. 117). Fragments of basic volcanic glass are indeed described as common in all deep-sea deposits, and as especially abundant in the Red Clay areas of the Pacific. The characters of such glass and its manner of decomposition are also discussed, and an analysis of the palagonitic matter is given on p. 307 of the 'Challenger' Report. This analysis (B) we place side by side with that of the clay isolated by our analysis re-calculated to a percentage composition (A), and also one of a palagonite (C) from Climbach, near Giessen (Streng, Neues Jahrb. 1888, vol. ii. p. 224), for the reference to which we are indebted to Mr. J. J. H. Teall, F.R.S.:—

	A.	B.	C.
Silica	49·67	44·73	50·02
Alumina	17·91	16·26	13·06
Peroxide of iron	15·31	14·57	17·60
Peroxide of manganese	2·29	2·89	—
Lime	1·02	1·88	2·82
Magnesia	·82	2·23	4·57
Potash	1·35	4·02	·55
Soda	2·33	4·50	·84
Water	9·31	9·56	10·54
	100·01	100·64	100·00

We do not doubt that the decomposition of the basic pumice which is also very abundant in the Pacific would result in the formation of a similar material. The close connexion between this pumice and the volcanic glass is shown by the following analyses taken from the 'Challenger' Report (pp. 297, 307):—

	Basic Glass. 1.	Basic Glass. 2.	Basic Pumice.
Silica	46·76	49·97	50·56
Alumina	17·71	11·68	10·30
Ferric oxide	1·73	2·45	4·95
Ferrous oxide	10·92	10·60	7·59
Manganese oxide	·44	traces	·14
Lime	11·56	11·20	9·35
Magnesia	10·37	12·84	9·27
Potash	·17	·25	1·24
Soda	1·83	1·60	2·81
Titanic acid	—	—	·80
Water	—	—	1·70
	101·49	100·59	98·71

The clay is formed by the hydration and oxidation of these substances in the presence of sea-water. Dr. Murray remarks that, in comparing the analysis of the palagonite with that of the anhydrous silicate from which it was derived, it is seen that 'lime and magnesia are eliminated, the protoxide of iron passes into peroxide, alkalies derived from the action of sea-water enter into combination, the

quantity of alumina remaining almost constant' (*op. cit.* p. 307). The clay is only this palagonite in a still more disintegrated form.

We are therefore in complete agreement with Dr. Murray's views regarding the origin and formation of the argillaceous material which covers such large areas of the ocean-floor, and we think that our analysis supplies the chemical confirmation of his conclusions which was wanting in those analyses that were before him when writing his Report.

There remains, however, an interesting ingredient which has not been fully considered by Dr. Murray, and this is the presence of disintegrated but comparatively unaltered acidic pumice or pumiceous sand in the deposit. The peculiarity of this is that it represents a pumice in which the proportion of alkalies is very high, the amount of soda being especially large. Its re-calculated percentage composition is given below in column A. Column B shows the composition of a piece of pumice from the 'Challenger' collection analysed by Dittmar, after treatment which freed it from its decomposed external portion.[1] An analysis of a pumice from Cotopaxi is given in column C for comparison.[2]

	A.	B.	C.
Silica	67·84	76·41	73·77
Alumina	15·39	15·53	10·83
Ferric oxide	·68	trace	1·80
Lime	1·37	2·11	1·21
Magnesia	3·52	·40	1·30
Potash	4·12	2·26	3·90
Soda	7·05	2·98	4·29
Moisture	—	·20	2·85
	99·97	99·89	99·95

It will be noticed that these are all pumices, in which there is little or no iron, and in which the amount of soda exceeds that of potash, the excess of soda in the pumice from the Red Clay being especially large. They seem to belong to lavas which would solidify into keratophyres or soda-felsites, and we give analyses of three keratophyres for comparison, A being one from near Rübeland in the Harz, quoted from Zirkel, 'Lehrb. d. Petrogr.' 2nd ed. 1894, vol. ii. p. 334, B and C soda-felsites from Co. Wicklow, Ireland.[3]

	A.	B.	C.
Silica	61·67	71·6	77·8
Alumina	17·47	16·9	13·2
Ferric oxide	1·37	·3	·2
Ferrous oxide	3·92	·9	·7
Lime	·18	2·2	trace
Magnesia	2·13	·6	trace
Potash	3·38	1·3	2·1
Soda	8·52	4·7	5·1
Water and loss by ignition, etc.	·90	1·1	·6
	99·54	99·6	99·7

[1] 'Challenger' Reports, Deep-Sea Deposits, p. 457.
[2] Taken from Watt's Dictionary of Chemistry, art. Pumice.
[3] See Hatch, Geol. Mag. 1889, p. 546.

We learn from the 'Challenger' Report on Deep-Sea Deposits (p. 349) that fragments of light-coloured acidic pumice and of blackish basaltic pumice were of frequent occurrence in these Pacific dredgings, the most numerous being pebbles of liparitic pumice of a whitish or greyish colour when little altered. Again (p. 297), 'Minute fragments of the different varieties of pumice noted above can be detected in all marine deposits, and in some areas the greater part of a red clay, or of the residue of a calcareous ooze after removal of the carbonate of lime by dilute acid, may be made up of minute fragments and splinters of pumice.'

The presence of this pumiceous sand appears to account for the large percentage of silica in the insoluble residue of Dr. Brazier's analyses, which was also a puzzle to Dr. Murray. Remarking on this, he says:—'Here too there is an excess of silica . . In certain cases the presence of quartz must be admitted, for the quantity of bases is not sufficiently high, but these grains of quartz do not belong normally to the Red Clay . . . We have seen that special conditions, such as atmospheric currents and glacial phenomena, may serve to account for the presence of quartz in certain regions where Red Clays are in process of formation' (*op. cit.* p. 201).

It is obvious, however, that an occasional and local cause is not an explanation of an universally high percentage of silica in the insoluble residue of Red Clays. Moreover our analysis, as well as microscopical examination, shows the amount of quartz to be infinitesimal. When the constituents of Red Clay are properly separated, the difficulty ceases to exist, the palagonitic earth and the pumiceous sand being compounds which will account for all the silica present in the deposit.[1] On reference to Dr. Brazier's analyses of this Red Clay, it will be seen that he estimated the total silica at 59·77 per cent. We find only 54·09, a difference of 5·68. Dr. Brazier, however, did not determine the alkalies, which we find to amount to 6·07, a very close approximation to the difference in the estimates of silica. We conclude, therefore, that Dr. Brazier did not determine the silica directly, but calculated it by difference, and that his amount really includes the alkalies.

III. Comparison with the Coloured Earths of Barbados.

In the analyses of the red and yellow earths of Barbados, published in our former paper, the constituents were not separated into groups as in that of the recent Red Clay above given. For the purpose of comparison, therefore, we must arrange the results of the latter in a similar form; this we have done below in column A, placing beside it three analyses of the Barbadian earths, namely B, a bright red clay from Castle Grant; C, a yellow one from Mount Hillaby; and D, a light red clay from Mount Hillaby:—

[1] Microscopical examination of the pumiceous residue of the Red Clay shows that it also contains a few fragments of felspar and similar minerals, not decomposed.

	A.	B.	C.	D.
Loss on ignition	6·67	8·55	4·72	7·10
Quartz	·01	·41	·73	·76
Colloid silica	4·61	4·98	5·76	4·85
Combined silica	49·48	47·65	54·50	51·70
Peroxide of iron	10·55	4·86	6·95	2·84
Alumina	15·71	25·20	21·03	25·48
Peroxide of manganese	1·56	3·05	1·24	2·71
Lime	1·01	trace	—	—
Magnesia	1·38	2·57	2·62	2·68
Potash	1·88	·18	·50	·10
Soda	3·22	2·55	1·95	1·78
Carbonate of lime	·92			
Sodium chloride	1·84			
Magnesium chloride	·96			
Sulphate of lime	·80			
	100·60	100·00	100·00	100·00

It will be seen that the chief differences are that the recent clay contains sea-salts, a little calcium carbonate, less alumina and more peroxide of iron than the Tertiary deep-sea clays. But if such a recent clay were exposed to the action of percolating water, the sea-salts, the calcium carbonate, and some of the iron would be dissolved out, with the result that the proportions of silica and alumina would be increased. If all the sea-salts, the carbonate of lime, and half of the iron were dissolved from the clay A, the remainder would contain 17·6 of alumina and 55·44 of combined silica.

There is still a difference between these amounts and those of the Barbados clays, for none of the latter contained quite so much silica or quite so little alumina. Still we found that the proportions of silica (combined) varied from 43 to 54·5, and those of alumina from 21 to 31·5, the amount of alumina thus being always large.

We believe that all these deep-sea clays are mainly formed by the suboceanic decomposition of volcanic glasses and pumices, and that the variations in the amounts of silica, alumina, and alkalies which they contain depend on the relative proportions of the basic and acid varieties of these materials. From the large proportion of alumina in the Barbadian clays it would appear that they have been derived from the decomposition of very basic materials, while the high percentage of silica in many recent deep-sea clays is evidently due to the presence of a highly acidic pumice.

In this connexion it is noticeable that the amount of potash is very small in the Barbadian clays, while that of soda is comparatively large. In this and other respects the similarity between the recent clay and the Tertiary clays is very striking, the minute quantity of quartz and the constant 4 or 5 per cent. of colloid (organic) silica being essential characteristics of deep-sea clay, whether ancient or modern.

As regards the composition of the Barbadian clays, we find that if the pumiceous dust which actually fell on Barbados in 1812 from the eruption of St. Vincent[1] were mixed with a clay such as we

[1] See analysis in our paper on the Oceanic Deposits of Barbados, Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 192.

have isolated from the Pacific deposit, and in the same proportions, namely about one third of the former to two thirds of the latter, the composition of the resulting compound would approach very nearly that of the Tertiary deep-sea clays, differing only in having larger amounts of iron and lime. Such difference would of course soon be removed by the action of percolating water. As the point is of some interest, we append the calculated composition of such a mixture :—

Water	7·13	
Colloid silica	4·15	
Combined silica	46·96	
Alumina	19·22	
Iron oxides	12·91	=99·94
Manganese peroxide	1·53	
Lime	3·06	
Magnesia	1·20	
Potash	1·25	
Soda	2·53	

IV. The Calcareous Oozes.

In dealing with the three samples of calcareous oozes with which Dr. John Murray kindly supplied us, the same methods were employed as in the case of the Red Clay. As might be expected, the greater portion of each sample consists of calcium carbonate, the quantity of organic silica is generally small, and that of quartz much smaller; there is always a certain amount of argillaceous or earthy matter, and a variable proportion of adherent sea-salts.

As both the calcium carbonate and the colloid silica may be regarded as derived from organisms, the results of the analyses may be arranged under three heads :—(1) Organic constituents, (2) Argillaceous and earthy matter, (3) Adherent sea-salts.

The first sample (A) was from a 'Challenger' dredging in the Pacific, Station 224, lat. 7° 45′ N., long. 144° 20′ E., depth 1850 fathoms.

The second sample (B) was also from a 'Challenger' dredging, in the South Atlantic, Station 338, lat. 21° 15′ S., long. 14° 2′ W., depth 1990 fathoms.

The third (C) was obtained by the 'Buccaneer' in 1886, from a dredging in the South Atlantic, lat. 0° 1′ S., long. 15° 56′ 5″ W., depth 1845 fathoms.

Each was dried at a temperature of from 230° to 240° Fahr. before analysis, and it should be mentioned that we had asked Dr. Murray to furnish us with samples of the more highly calcareous oozes, such as might be comparable with Tertiary and Cretaceous chalks. This accounts for their all containing a very high proportion of carbonate of lime.

The following are the analyses of these samples :—

Organic Constituents.	A.	B.	C.
Organic matter and combined water	1·82	1·78	·86
Calcium carbonate	79·79	91·17	89·50
Calcium phosphate	·24	·31	·11
Colloid silica	3·87	·77	1·61

Argillaceous and Earthy Constituents.	A	B.	C. (*cont.*).
Iron peroxide	3·41	1·23	1·22
Alumina	·42	·44	·79
Manganese peroxide	·35	·38	·38
Lime	1·65	·25	·42
Magnesia	·81	·12	·04
Potash	·28	·17	·17
Soda	·35	·04	·25
Combined silica	2·27	1·19	1·27
Quartz	·17	·04	·55
Adherent Sea-salts.			
Sodium chloride	2·67	1·79	2·11
Magnesium chloride	1·17	·27	·27
Calcium sulphate	·73	·42	·32
Potassium sulphate	—	traces	traces
Totals	100·00	100·37	99·87

On referring to the 'Challenger' Report, we find that analyses were made by Dr. Brazier of the samples A and B, but that in the case of A it was the coarser part only that was analysed, 'after the finer parts had been washed away (*op. cit.* p. 441).' The following is Dr. Brazier's analysis of this coarser part:—

Loss on ignition		1·50	
Soluble in hydrochloric acid. 97·57 p. c.	Alumina	1·25	=100·00
	Ferric oxide	·47	
	Calcium phosphate	·28	
	Calcium sulphate	·29	
	Calcium carbonate	93·14	
	Magnesium carbonate	·57	
	Silica	1·57	
Insoluble—Alumina, ferric oxide, and silica		·93	

On comparing this with our analysis it is evident that the composition of the coarser part is very different from that of the mass. The coarser part contains 93·71 per cent. of carbonates, while the amount in the whole mass according to our analysis is about 80[1]; consequently in the part which was washed away there must have been much less than 80 per cent.

It is true that in Dr. Brazier's analysis the adherent sea-salts were almost entirely removed in the washing process, and that if we had removed them from our sample before analysis the amount of carbonate of lime would have come out higher, namely, 83·61 per cent. But to obtain a mean of 83·61 per cent. when one portion has 93·71, the other, *i. e.* the finer part, must have had only 73·51 per cent. of carbonate of lime.

A glance at the microscopical structure of the material (see p. 327) will explain this difference, for the coarser part consists almost entirely of *Globigerina*-tests, and is therefore highly calcareous, while the finer part would naturally be less calcareous and more siliceous. Thus the amount of siliceous and earthy matters in

[1] Dr. Murray's determination was 79·20 per cent., 'Challenger' Reports, Deep-Sea Deposits, p. 108.

Dr. Brazier's analysis is only 4·22, the total amount of these ingredients in the ooze as a whole is 13·58, and when corrected for adherent sea-salts, it would be 14·23 per cent. From this we may infer that the siliceous ingredients in the finer part of the ooze would amount to 24·24 per cent.

We thus obtain a good idea of the composition of the finer part of the sample, and it is interesting to observe that it shows an approach to that of the coarser parts of some 'Red Clays.' Thus a Red Clay from Station 5, analysed after its finer part had been washed away, contained 61 per cent. of carbonate of lime, and 34 per cent. of siliceous matter. Arranging the ingredients of the finer part of the *Globigerina*-ooze, calculated differentially in the manner above indicated, and placing them side by side with those of the washed Red Clay, we have :—

	Finer part of *Globigerina*-ooze.	Coarser part of Red Clay.
Water and organic matter	2·14	2·60
Carbonate of lime	73·51	61·01
Phosphate of lime	·20	2·09
Residual sulphate of lime	—	·29
Silica and silicates	24·24	34·01
	100·09	100·00

This tends to show that the materials of Red Clay are universally distributed over the ocean-floor, and are only masked by the calcareous ingredients of the *Globigerina*-ooze—a conclusion which is quite in harmony with Dr. Murray's view of the origin of Red Clay.[1]

There is no doubt that the Red Clay from Station 5 contained a larger amount of calcareous matter than usual, but that the coarser parts of other Red Clays bear the same relation to the finer parts is shown by two other analyses of such clays from which the finer part had been washed away. One of these gave 36·80 per cent. and the other 38·13 per cent. of calcium carbonate (see 'Challenger' Reports, Deep-Sea Deposits, p. 198), amounts which are very high when we remember that the average amount of calcium carbonate in red clays from between 2000 and 3000 fathoms is only 7·77 per cent. (*op. cit.* p. 193).

Returning to our analysis of the *Globigerina*-ooze from Station 224, it is satisfactory to find that it agrees very closely with the estimate of its composition made by Dr. Murray himself on p. 108 of the Report. In this and other similar analyses Dr. Murray states that the amount of calcium carbonate was ascertained by actual quantitative analysis from the total amount of carbon monoxide present; but the amount of siliceous residue was estimated by subtracting the weight of the calcium carbonate from 100. It is evident, therefore, that the amounts entered under the head of fine washings

[1] Compare Klement's analyses of the portions of these oozes that are insoluble in dilute acid, 'Challenger' Reports, Deep-Sea Deposits, pp. 220 & 221.

include sea-salts, organic matter, and other ingredients. Allowing for this, it will be seen that the two estimates agree very closely:—

	Analysis by Harrison & Williams.	Estimate by Dr. John Murray.
Carbonate of lime	79·79	79·20
Siliceous organisms	3·87	5·00
Water and organic matter	1·82	15·80
Minerals and fine washings	9·71	
Adherent sea-salts	4·57	
	99·76	100·00

The second sample (B) analysed by us was also analysed in mass by Dr. Brazier, and the results obtained by him are as follows[1]:—

Loss on ignition after drying at 230° F.		1·40	
Soluble in hydrochloric acid.	Alumina	·65	=100·00
	Ferric oxide	·60	
	Calcium phosphate	·90	
	Calcium sulphate	·19	
	Calcium carbonate	92·54	
	Magnesium carbonate	·87	
	Manganese oxide	nil.	
	Silica	1·36	
Insoluble—Alumina, ferric oxide, and silica		1·49	

On comparing this with the analysis of B on p. 323, the mistake made in digesting the material in boiling hydrochloric acid is shown by the difference in the amounts of insoluble residue and soluble silica. By Dr. Brazier's method only 1·49 of insoluble residue was left, whereas the sample really contains nearly 4 per cent. of silicates, which ought to be reckoned as insoluble matter. Again, 1·36 per cent. of silica was rendered soluble by Dr. Brazier's treatment, but the amount of soluble colloid silica present is only 0·77 per cent.

Another point of some importance is that Dr. Brazier reckons all the magnesia as carbonate, and makes the total amount of calcium and magnesium carbonates come to 93·41 per cent. We did not find enough carbonic acid to combine with the magnesia, and consider this to be partly in the state of chloride and partly as silicate; the magnesium chloride and calcium sulphate being part of the adherent or occluded sea-salts.

On referring to the 'Challenger' Report (p. 446) we find a subsequent note by Klement, stating that 1·0185 gram of the ooze dried at 110° C. gave 0·4120 gram of carbonic acid, corresponding to 0·9364 gram of carbonate of lime, which is equivalent to 91·94 per cent. This is a close approximation to our own result, 91·17 per cent.

Of the third sample, obtained by the 'Buccaneer,' no previous analysis has been published. It is seen to be a highly calcareous ooze very similar to the 'Challenger' sample B from Station 338,

[1] 'Challenger' Report on Deep-Sea Deposits, p. 444.

this similarity being even more apparent when the adherent sea-salts are removed; the 'Challenger' sample then has 93·46 per cent. of calcium carbonate, and the 'Buccaneer' sample has just 92 per cent. The amounts of iron and manganese oxides are practically the same in both, and those of combined silica differ but little. The adherent sea-salts amount to 2·48 per cent. in the one, and 2·70 per cent. in the other.

V. Comparison with Tertiary and Cretaceous Chalk.

None of the Tertiary chalks of Barbados which we examined contained as much as 90 per cent. of calcium carbonate, because they are associated with radiolarian earths, and most of them include from 10 to 20 per cent. of siliceous organisms, and from 9 to 13 per cent. of clay. Several of them, however, contain about 80 per cent. of calcium carbonate, and these compare very well with the 'Challenger' sample A, so far as chemical composition is concerned—especially when the adherent sea-salts of the latter are subtracted, and the other ingredients are re-calculated to a percentage. This has been done, and the result tabulated under column A, beside which are placed the analyses of two Barbadian chalks taken from our former paper in this Journal, vol. xlviii. (1892) p. 185 :—

	'Challenger.' A.	Canefield.	Cleland.
Loss on ignition	1·90	2·59	1·84
Calcium carbonate	83·61	83·23	79·84
Calcium phosphate	·25	·35	·38
Colloid silica	4·05	5·02	7·36
Quartz	·17	·05	·01
Silicates, iron, etc.	8·96	6·28	9·65
Manganese peroxide	·36	1·43	·91
Alkalies	·65	·37	·01
	99·95	99·32	100·00

The other two oozes have an exceptionally large proportion of calcium carbonate, and are not therefore comparable with Barbadian chalks. These chalks have a greater resemblance to the oozes which contain between 60 and 80 per cent. of calcium carbonate, but we have not analysed any of these, and Dr. Brazier's analyses do not afford a sufficiently accurate basis of comparison. Attention, however, may be directed to the infinitesimal amounts of quartz which both oozes and chalks contain, the amount in the oozes ranging from ·04 to ·55, and in the chalks from ·01 to ·69.

With regard to Cretaceous chalk, few analyses have been made with that amount of care which is necessary for a proper comparison with our analyses of recent ooze. We decided, therefore, to have several samples of Middle Chalk analysed by the same methods. These analyses were carried out at Georgetown in the Government Laboratory under the supervision of one of us, and with the assistance of Mr. J. Williams. The results are as follows :—

	W.	X.	Y.	Z.
Organic matter, etc.	·57	·50	·10	·40
Calcium carbonate	95·20	97·02	96·15	94·94
Calcium sulphate	·17	·41	·29	·31
Magnesium carbonate	·68	—	1·34	·25
Colloid silica	·65	·45	·35	·48
Quartz	·55	·30	·15	·10
Clay, alumina, and magnesia	1·66	1·03	1·00	2·95
Iron peroxide	·40	·26	·28	·40
Manganese peroxide	·28	·05	·23	·27
Alkalies	·16	·04	·27	·23
	100·32	100·06	100·16	100·33

W is a sample from the lower part of the Melbourn Rock near Okeford Fitzpaine, Dorset.
X is a sample from the upper part of the same rock.
Y is Chalk about 60 feet above that rock at Hitchin.
Z is Chalk Rock with glauconite-grains from Aston Rowant, near Watlington in Oxfordshire.

The similarity between these and the two oozes marked B and C on p. 322 is very great. It must be remembered that, when the adherent sea-salts are allowed for, the proportions of calcium carbonate in these amount to 93·46 and 92 respectively. The Chalks differ chiefly in having less peroxide of iron than the oozes. The small amount of quartz, both in Chalk and ooze, is especially noticeable.

VI. Microscopical Structure of Oozes.

While the chemical composition of the three samples of ooze is very similar to that of certain kinds of chalk, both Tertiary and Cretaceous, the microscopical structure exhibits some differences.

The two Atlantic oozes, B and C of p. 322, have, in the mass, a distinctly granular appearance which is evidently due to the great abundance of robust, thick-walled tests of foraminifera. In a thin slice of the dried material *Globigerinæ* and other foraminifera are seen to occupy the greater part of the field; but the intervening matrix has the characters of chalk, consisting almost entirely of fine calcareous matter in which minute foraminifera and single-celled calcareous spheres with thin walls are abundant. These spheres are much more abundant in the 'Challenger' sample (B) than in the 'Buccaneer' sample (C).

We are indebted to Mr. William Hill, F.G.S., for the following observations on these oozes when examined with high powers:—

'The fine matrix shows no definite structure when seen under high powers, but the idea gradually possesses one that most of it must be foraminiferal débris. In the 'Challenger' specimen there are multitudes of exceedingly minute spicule-like bodies, club-shaped, with three hooks at the thinner end; they disappear when treated with acid. Coccoliths are present, but are small and thin. There is a fair number of radiolaria and diatoms in both specimens. A few grains of pumice also occur in both, but otherwise there is very little inorganic material.'

The Pacific ooze (A) has a less granular and a more chalky appearance. In section *Globigerinæ* are seen to be abundant and

thick-shelled, but are not so closely packed as in B and C; there is, moreover, a larger number of immature specimens. Mr. Hill reports that 'the matrix consists largely of calcareous particles derived from the *Globigerinæ*, but there is a certain admixture of minute siliceous particles and of sponge-spicules; a few entire radiolaria can also be seen, and I should have thought that there was more than 4 per cent. of such siliceous material. There is also a certain amount of very fine siliceous matter, which gives the matrix a peculiar translucent appearance similar to that which is seen in a section of marl or clay. This is probably hydrated silicate of alumina, and there is in one place a definite film, strong enough to carry part of the test of a *Globigerina* in section, and by polarized light separate calcareous atoms seem to float in the film, while the carrying material is extinguished on rotation.'

Dr. John Murray informs us that these are typical examples of the more calcareous oozes, and that deposits of a chalky character were not common among the 'Challenger' dredgings. It occurs to us that this may be due to the surface-character of the dredgings; the upper layers of the *Globigerina*-ooze must be full of the tests of recently dead foraminifera, but these tests have not had time to undergo alteration and disintegration. In the lower layers, which have been for a long time exposed to the chemical action of the sea-water, it seems likely that some alteration would take place. Probably many of the tests fall to pieces, thereby increasing the proportion of finely-divided material, and a certain amount of compression must also occur. If this view be correct, the resulting material would have as close a similarity to Chalk in structure as the surface-ooze has in chemical composition.

In conclusion we may remark that our examination of these recent deep-sea deposits, and a comparison of them with the raised Barbadian deposits, have only increased our conviction that the latter are truly of oceanic origin.

Discussion.

Mr. W. W. Watts congratulated the Authors on having been able to derive their information with regard to the Red Clay from actual specimens, while descriptions were all that were at present accessible to others. He wished to enquire by what means the pumiceous constituents had been separately estimated, and whether the manganese nodules had been excluded from the analysis of the Red Clay.

Dr. W. F. Hume said that the West Indian deep-sea deposits display the nearest resemblance of any to the Cretaceous deposits. Dr. Murray had already shown the great resemblance of certain marls in this region to the Chalk Marl, and now the Authors had shown that the *Globigerina*-oozes differ but little from those of the Turonian Chalk of England. As the West Indian region is one of the principal areas where assemblages of arenaceous foraminifera occur specifically identical with those of the Chalk Marl, the interest of these comparisons becomes considerably increased.

Dr. G. J. Hinde, Mr. Clement Reid, and Mr. J. E. Marr also spoke.

24. *On* Bones *of a* Sauropodous Dinosaur *from* Madagascar. By R. Lydekker, Esq., B.A., F.R.S., V.P.G.S. (Read February 6th, 1895.)

Originally described from the Lower Cretaceous and Jurassic rocks of England and other parts of Europe, the gigantic dinosaurs commonly known as sauropods have been subsequently discovered in great abundance in North America, while they have been recorded by myself some years ago from Southern India, and quite recently from Patagonia. We have thus evidence that the group had a very wide geographical distribution; and it is noteworthy that, while several of its North American representatives appear inseparable from their European allies, the Indian and Argentine forms are likewise referable to one and the same genus. Hitherto we have had no evidence of the occurrence of the group in Africa or Madagascar; and it is therefore a matter of considerable interest to be able to bring before the Society the fact that these gigantic dinosaurs were represented in the island last named.

Before proceeding to the consideration of the specimens themselves, it is important to mention that remains of a Mesozoic reptile of a Jurassic type have already been recorded from the island, and referred to the European genus *Steneosaurus*.[1] The presumption thus afforded of the occurrence of Jurassic strata in Madagascar is converted into a certainty by the discovery of a large series of molluscan remains belonging to forms characteristic of that period.[2]

The specimens that I have the opportunity of now bringing under the notice of the Society comprise a large series of reptilian bones collected by Mr. J. L. Last, at a spot about 20 miles to the eastward of the bay of Narinda, on the north-western coast. These bones, which have been purchased by the British Museum, include vertebræ, limb-bones, and portions of the pectoral and pelvic girdles of gigantic land-reptiles; and although the long bones are represented only by their extremities or fragments of the shafts, while the vertebræ are all more or less broken, yet many of the specimens are sufficiently well preserved to afford characters amply sufficient for defining the nature and affinities of the animals to which they belonged.

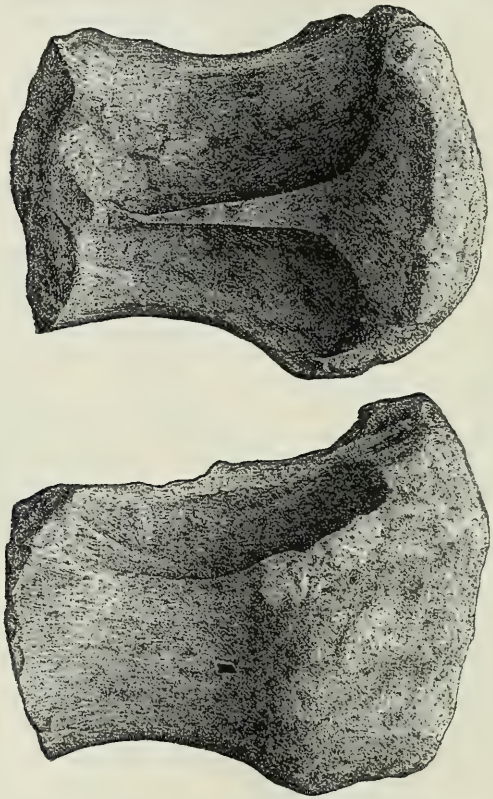
That the bones are those of dinosaurs is rendered certain by their huge size; while the same feature is likewise sufficient to indicate that they belong to the sauropodous section of that great group. If further evidence were required as to their sauropodous affinities, it is seen in the structure of the cervical and dorsal vertebræ described and figured below, which show the pits on the sides of the centra distinctive of the group in question.

The vertebræ are represented by specimens from the cervical, dorsal, lumbar, sacral, and caudal regions. Both the cervicals and dorsals are strongly opisthocœlous, and carry large lateral cavities; these cavities being apparently devoid of any channel of communication with the interior of the centrum, which seems to be solid;

[1] R. B. Newton, Geol. Mag. 1893, p. 193.
[2] *Id.* Quart. Journ. Geol. Soc. vol. li. p. 78.

and the bone between those of opposite sides being reduced to an exceedingly thin septum, extending upwards to form the floor of the neural canal. Whereas the best-preserved dorsal indicates an animal of the approximate dimensions of *Hoplosaurus armatus* of the English Wealden, a lumbar and first caudal are fully as large as the corresponding vertebra of the Oxfordian *Pelorosaurus Leedsi*.

Fig. 1.—*Superior and right lateral aspects of centrum of anterior cervical vertebra of* Bothriospondylus madagascariensis. (*About* $\frac{1}{3}$ *nat. size.*)



Of the three anterior caudal vertebræ preserved, one is also much larger than either of the other two, although it appears to have occupied a nearly similar position in the series. These facts seem to indicate that we have remains of more than a single individual to deal with, although I cannot satisfy myself that there is any evidence of a specific difference between the specimens.

Of anterior cervicals there are, as already mentioned, three examples of the centrum, one of which is much larger than the other two. In all the terminal extremities are imperfect. One of the smaller examples is represented in the accompanying illustration (fig. 1).

In all three specimens the centrum is somewhat narrow and

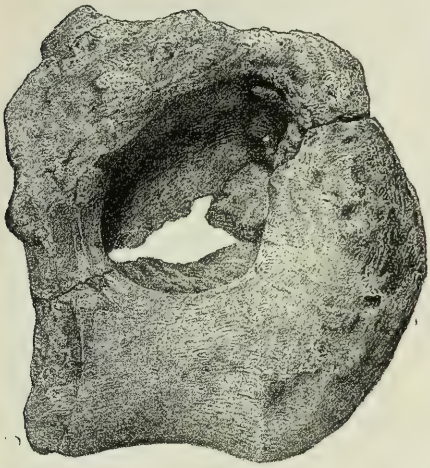


Fig. 2.—*Right lateral aspect of an imperfect late cervical vertebra of* Bothriospondylus madagascariensis. (*About* $\frac{1}{3}$ *nat. size.*)

elongated, while the inferior surface is rounded. The lateral cavities are large and rounded: their outer inferior margin not being raised above the general level to form a pocket. The narrow septum between them is, as in the figure, well exhibited. In the figured example the length is $6\frac{3}{4}$, and the posterior width $5\frac{1}{2}$ inches; the corresponding dimensions in the larger example being, severally, 9 and $6\frac{3}{4}$ inches.

The specimen represented in fig. 2 is an imperfect vertebra from the hinder part of the cervical region, exhibiting the contour of the entire lateral cavity. Although shorter than the anterior cervicals, it is still narrow, and rounded inferiorly. The septum between the two lateral cavities is so thin that in 'developing' it has been broken through. The cavity is irregularly pear-shaped, with the longer diameter directed upwards and backwards. The lower boundary of the lateral is raised up as wall for a considerable distance above the floor, so as to convert the lower portion of the cavity into a pocket. The length of the centrum of this specimen is $6\frac{1}{2}$ inches, and its proximal width is $5\frac{3}{4}$ inches.

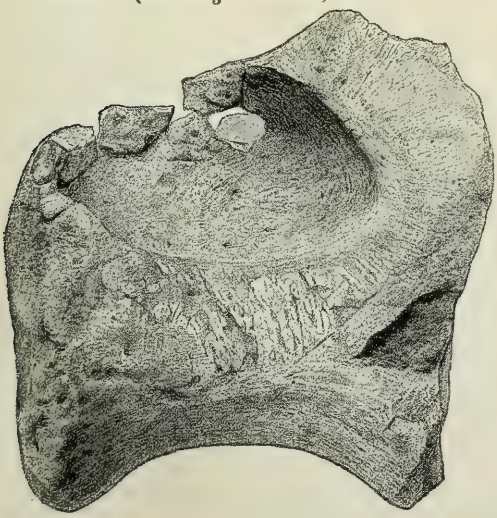


Fig. 3.—*Left lateral aspect of centrum of dorsal vertebra of* Bothriospondylus madagascariensis. (*About* $\frac{1}{3}$ *nat. size.*)

The dorsal vertebræ are represented by the specimen shown in fig. 3,

which probably belongs to the anterior part of the series, and is broken off along the line of the floor of the neural canal. The lateral cavity, although incomplete, appears to be oval in form, with its longer axis longitudinal; and its lower outer margin is not produced upwards to form a pocket. The centrum is shorter and wider than in the cervicals, with its lower surface broad and flat; in all of which respects it agrees exactly with the corresponding vertebræ of *Hoplosaurus*. The anterior terminal convexity is also less strongly marked than in the cervicals. In length this specimen measures $7\frac{3}{4}$ inches, while its distal width is about $7\frac{1}{2}$ inches.

The centrum and base of the neural arch of the very large vertebra shown in fig. 4, from the presence of a small lateral immediately beneath the base of the transverse process, I take to be the last lumbar rather than the first caudal. The centrum is very short and wide, with its anterior terminal face somewhat saddle-shaped from above downwards, and the posterior extremity flat. The length of the centrum is 5 inches, and its posterior width upwards of 10 inches.

The sacrum is represented by two fragments, showing the anterior and posterior terminal surfaces, and probably belonging to a single individual. From these specimens it is probable that there were at least four segments in this portion of the vertebral column. The terminal faces are quite flat, and there are no lateral pits to the centra.

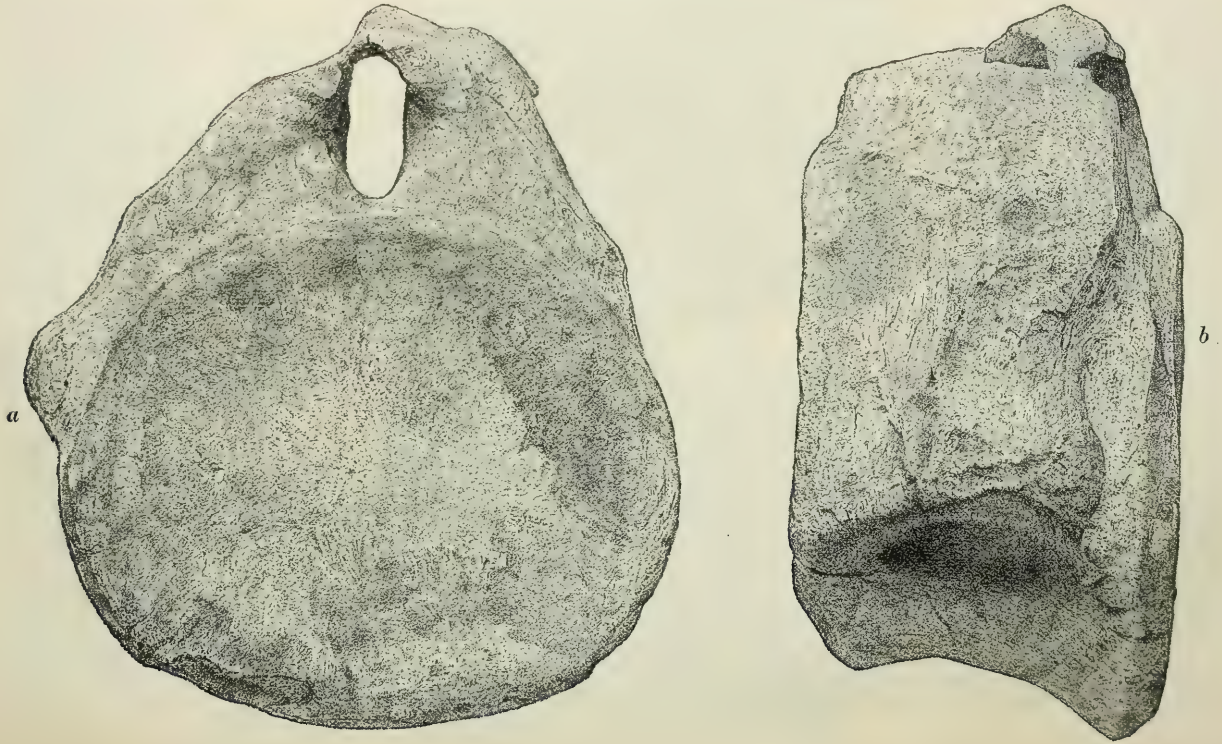
The centrum of a first caudal vertebra of large size is characterized by its extreme shortness and width: the anterior face being saddle-shaped from above downwards, and the posterior cupped. The length is $4\frac{3}{4}$, and the width 10 inches.

Both in form and size this vertebra closely resembles the anterior caudals of *Pelorosaurus Leedsi*, from the Oxford Clay of Peterborough, although the latter are abnormally shortened from the effects of pressure. In this, as well as in the more posterior caudals, there are no lateral pits.

From among several examples of vertebræ occupying a more posterior position in the caudal series, the one represented in fig. 5 (p. 334) is selected for illustration. Relatively longer than the last, this specimen has its anterior face flat and heart-shaped, while the hinder face is somewhat cupped. Chevron-facets are shown on both the front and hind borders of the inferior surface, indicating that the chevrons articulated with two adjacent vertebræ. The posterior caudals, of which there are several more or less imperfect examples, have the general form common to sauropodous dinosaurs, with flat terminal faces.

Since the remains of the pectoral and pelvic girdles, as well as the limb-bones, are very imperfect and broken, it seems unnecessary to describe them, more especially as bones like the femur do not generally afford any very well-marked generic characters. It may be mentioned, however, that the two extremities of a femur indicate a bone apparently closely resembling in size and form the femur of *Cetiosaurus oxoniensis*.

Fig. 4.—*Terminal and left lateral aspects of imperfect last lumbar vertebra of* Bothriospondylus madagascariensis.
(*About* $\frac{1}{3}$ *nat. size.*)



Regarding the affinities of the gigantic dinosaur represented by the above-described vertebræ, the flat terminal faces of the posterior caudal vertebræ indicate that it cannot be identified with *Titanosaurus* of the Cretaceous of India, England, and Patagonia. From *Hoplosaurus* (*Ornithopsis*) it is at once distinguished by the narrow septum between the lateral cavities of the centra, the septum of the latter being of great thickness, and, like the rest of the centrum, much cancellated. Moreover, there is no communication between

Fig. 5.—*Left lateral and inferior aspects of the centrum of an early caudal vertebra of* Bothriospondylus madagascariensis. (*About* $\frac{1}{3}$ *nat. size.*)

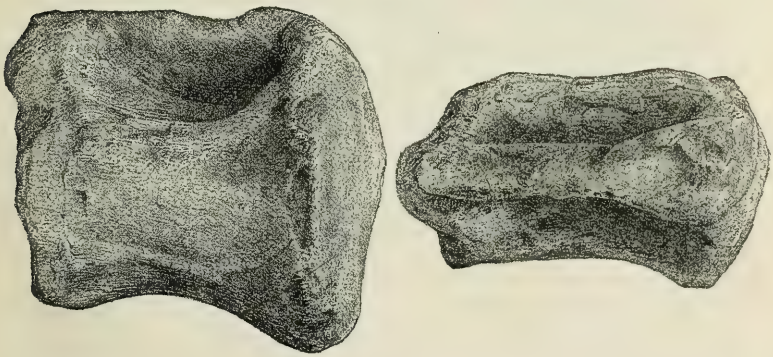
the lateral cavities of the centrum and the interior, as is the case in *Hoplosaurus*. Similar differences serve to distinguish the vertebræ from those of *Morosaurus*.[1]

Unfortunately the dorsal vertebræ of *Cetiosaurus oxoniensis* are so badly preserved, and so imperfectly figured, that I am unable to say anything regarding their lateral cavities; and I am unacquainted with any specimens of those of *Pelorosaurus*. From the resemblance of the other remains of these genera to those of *Atlantosaurus*, *Brontosaurus*, etc., it is, however, quite probable that at least in the typical Wealden representative of the latter the vertebræ were of the *Hoplosaurus*-type, as are those of the American genera.

[1] See Lydekker, Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 277, fig. 1.

There are, however, in the British Museum certain dorsal vertebræ which, although of much smaller dimensions, agree precisely with those of the form under consideration in structure. The first of these are from the Kimeridge Clay, and were described by Owen under the name of *Bothriospondylus suffossus*, of which genus they constitute the type. They indicate a very immature dinosaur, and from their immaturity I have thought that they might belong to the young of one of the other genera.[1] These specimens have the lateral pits precisely similar to those in the dorsal vertebra of the Malagasy form, while a comparison with the latter shows that the dividing septum was of the narrow type. The whole bone, moreover, appears to be devoid of cancellation. Formerly I thought it possible that these features might be those of the immature state of forms like *Hoplosaurus*, but the specimens before us clearly demonstrate that this is not the case. Another dorsal vertebra of similar type, from the Forest Marble of Wiltshire, was likewise referred by Owen to *Bothriospondylus*, under the name of *B. robustus*. This specimen, represented in fig. 6, likewise agrees in all respects

Fig. 6.—*Lateral and superior aspects of centrum of dorsal vertebra of* Bothriospondylus robustus. (*About* $\frac{1}{3}$ *nat. size.*)



with the dorsal vertebra from Madagascar; and it is quite clear that, with the materials at present available, it is impossible to separate generically the two forms. I accordingly propose to refer the Malagasy dinosaur to the genus *Bothriospondylus* (which is now for the first time susceptible of definition) under the name of *B. madagascariensis*, taking the dorsal vertebra represented in fig. 3 (p. 331) as the type: the species being sufficiently characterized by its large size.

We have thus evidence that *Bothriospondylus* indicates a type of sauropodous dinosaur quite distinct from, and apparently much less specialized than, the Atlantosauridæ (in which *Hoplosaurus* and

[1] See Cat. Foss. Rept. Brit. Mus. pt. iv. (1890) p. 242.

probably *Pelorosaurus* may be provisionally included). Unfortunately, as already said, I cannot be sure as to *Cetiosaurus*, although I am inclined to think that the vertebræ had pits of a different type from those occurring in *Bothriospondylus*. If this be so, the latter genus cannot be included in the Cetiosauridæ; and as it certainly indicates a family-type distinct from the Atlantosauridæ, the name Bothriospondylidæ may be provisionally suggested.

There is, unfortunately, a considerable degree of doubt as to whether the generic name *Bothriospondylus* is entitled to stand, since, as I have shown elsewhere,[1] it is highly probable that *B. robustus*, which cannot be generically separated from the type-species, is really identical with *Cardiodon*, described at a much earlier date upon the evidence of a tooth. If this supposition is eventually verified, the name *Bothriospondylus* will have to yield to *Cardiodon*, and Bothriospondylidæ to Cardiodontidæ.

The identification of the Malagasy dinosaur with a type occurring in the Upper and Lower Jurassic of England, but unknown in the Cretaceous, harmonizes with the reference of some of the fossiliferous strata of Madagascar to the former period.

Discussion.

The President remarked upon the great interest attaching to the discovery of an *Ornithopsis*-like dinosaur in Madagascar, in rocks of supposed Jurassic age, and referred to the recent paper by the Rev. Richard Baron, in which he described Jurassic beds as occurring in the North-west of Madagascar, where these remains were reported to have been obtained.

Prof. Hull, Prof. Seeley, and Mr. E. T. Newton also spoke, and the Author replied.

[1] Cat. Foss. Rept. Brit. Mus. pt. iv. (1890) p. 236.

25. *A* Comparison *of the* Permian freshwater Lamellibranchiata *from* Russia *with those from the* Karoo System *of* South Africa. By Dr. Wladimir Amalitsky, Professor of Geology and Palæontology in the University of Warsaw. (Communicated by Dr. Henry Woodward, F.R.S., P.G.S. Read April 3rd, 1895.)

[Plates XII. & XIII.]

Introduction.

Some palæontologists, such as Owen [1] (1876), Twelvetrees [2] (1880), Trautschold [3] (1884), and others, have pointed out the resemblance which exists between the reptilian fauna of Perm, in Russia, and that of the Karoo formation of South Africa. This similarity was based on the fact that the reptiles of Perm described as *Rhopalodon*, Fisch., *Brithopus*, Kut., *Orthopus*, Kut., *Deuterosaurus*, Eichw., *Cliorhizodon*, Tul., *Oudenodon*, Traut., and others were referred to the Theriodontia, a group represented in the Karoo Series of South Africa. The Russian Permian reptiles referred to have been recently studied by Seeley,[4] who has come to the conclusion that they are closely allied to the South African types, but cannot be placed in the same subordinate groups. This author considers them as a new group, Deuterosauria, exhibiting a strong affinity with both the Placodontia and Theriodontia.

In 1892,[5] when describing the lamellibranchiate fauna from the Oka-Volga basin, I pointed out that the typical shells called *Palæomutela* from these deposits were also known from the Karoo Series of South and Central Africa, and had been described as *Iridina* by Daniel Sharpe [6] and Prof. T. Rupert Jones.[7] At that time, not being in possession of the original forms from the Karoo Series, I, of course, could answer only for the identity of the genus, though, judging from the description given by Daniel Sharpe and Rupert Jones, it was easy to observe that they possessed characters corresponding to those which I referred to the group of *Palæomutela Inostranzewi*. I then expressed the opinion that, in consequence of so wide a distribution of *Palæomutela*, the species of this genus,

[1] Owen, R., 'On Evidences of Theriodonts in Permian Deposits elsewhere than in South Africa,' Quart. Journ. Geol. Soc. vol. xxxii. p. 352.

[2] Twelvetrees, W. H., 'On Theriodont Humeri from Upper Permian in Orenburg,' Bull. Soc. Imp. Nat. Moscou, vol. lv. pt. i. p. 123.

[3] Trautschold, 'Die Reste permischer Reptilien des palæontol. Cabinets d. Univ. Kasan,' Nouv. Mém. Soc. Imp. Nat. Moscou, vol. xv. (1884).

[4] Seeley, H. G., 'Further Evidences of the Skeleton in *Deuterosaurus* and *Rhopalodon* from the Permian rocks of Russia,' Phil. Trans. Roy. Soc. vol. clxxxv. (1894) p. 663.

[5] 'Ueber die Anthracosien der Permformation Russlands,' Palæontographica, vol. xxxix. p. 209.

[6] Sharpe, D., Trans. Geol. Soc. ser. ii. vol. vii. (1852) p. 226.

[7] Jones, T. R., Geol. Mag. 1890, pp. 410 and 557.

after a closer study of the lamellibranchiata from the Karoo formation, might perhaps prove to be of value for instituting a parallel between the homotaxial deposits of the Russian Permian and the Karoo system of South Africa.

My recent studies of some lamellibranchiata from the Beaufort Beds of the Karoo system of South Africa, kindly placed at my disposal by the staff of the British Museum of Natural History (David Fraser collection from Bedford, and fossils from the shales at Kimberley), and of those in the Museum of the Geological Society of London (Bain and Rubidge collection from Graaf Reinet), enable me to state that they are extremely like those from the Permian freshwater deposits of Russia.

From the Karoo system (Beaufort Beds of Graaf Reinet) of South Africa, the following lamellibranchiata were described by Daniel Sharpe:[1] *Iridina* (?) *rhomboidalis*, *Iridina* (?) *ovata*, *Iridina*, sp., and *Cyrena*, sp. Prof. T. Rupert Jones[2] has described *Cyrena* (?) *neglecta* from the village of Balfour on the right bank of the Kat River, north of Graaf Reinet. After the study of the above-mentioned palæontological material I have defined the following forms:—

I. Group of *Palæomutela Inostranzewi.*

1. *Palæomutela rhomboidalis*, Sharpe (Beaufort Beds, Graaf Reinet).
2. *Palæomutela ovata*, Sharpe (*ibid.*).

II. Group of *Palæomutela Keyserlingi.*

3. *Palæomutela*, cf. *Keyserlingi*, mihi (*ibid.*).
4. *Palæomutela*, n. sp., aff. *orthodonta*, mihi (Shales at Kimberley Diamond Mines).
5. *Palæomutela trigonalis*, mihi (*ibid.*).
6. *Palæomutela*, n. sp., aff. *Golowkinskiana*, mihi (*ibid.*).

III. Group of *Palæomutela Verneuili.*

7. *Palæomutela semilunulata*, mihi (Beaufort Beds, Graaf Reinet).

IV. Group of *Palæomutela Murchisoni.*

8. *Palæomutela Murchisoni*, mihi (Beaufort Beds, Bedford).
9. *Palæomutela plana*, mihi (Beaufort Beds, Graaf Reinet).

V. Group of *Palæanodonta Fischeri.*

10. *Palæanodonta subcastor*, mihi (*ibid.*).
11. *Palæanodonta okensis*, mihi (*ibid.*).

All these groups and the following species—*Palæomutela Keyserlingi*, *P. trigonalis*, *P. semilunulata*, *P. Murchisoni*, *P. plana*,

[1] Trans. Geol. Soc. ser. 2, vol. vii. (1852) p. 226.
[2] Geol. Mag. 1890, p. 410.

P. subcastor, and *P. okensis*—are known in Russia from the upper horizons (A, B, C) of the Permian marls and sandstones of the Oka-Volga basin.[1] These upper horizons, according to the facts explained in my above-quoted paper,[2] I determine as the freshwater equivalent of the German Zechstein. Consequently, the Beaufort Beds of the Karoo Series, if considered as a homotaxial equivalent of those deposits, ought to be regarded as Upper Permian. But it is necessary to remark here that, with regard to the age of these rocks, Russian geologists cannot come to any fixed conclusion. The majority refer them to the Upper Permian, and only a few regard them as passage-beds between Permian and Trias. From what I have said above it is evident that the lamellibranchiata of the Upper Permian marls and sandstones of Russia resemble those from the Beaufort Beds of South and Central Africa. The Permian freshwater lamellibranchiata of Russia, which bear traces of genetic relationship with the Carboniferous Anthracosidæ, and were already well represented in Permo-Carboniferous and Lower Permian times, are undoubtedly much older than the African fauna of the Beaufort Beds; this, we may conclude, emigrated from Russia. It is probable that the Gondwána Beds of India have been the connecting-link between these deposits. But even if we admit, during the Permian epoch, the existence of an uninterrupted Russian-Indo-African Continent, the similarity of the freshwater fauna of such distant localities as Eastern Russia and South and Central Africa will still remain one of the most interesting problems of geology. The flora and even the rich vertebrate fauna from these Russian Upper Permian deposits, which I consider as homotaxial and synchronous with the Beaufort Beds of the Karoo Series, have not yet been described. The numerous remains of reptiles found in these deposits will probably prove, after a close study, to have a greater resemblance to the African Theriodontia than the new group of Deuterosauria, created by Prof. H. G. Seeley, which includes forms from the lower horizons of the Russian Permian formation.

Description of Fossils.

During my residence in London I have been enabled to study the following collections from the Karoo Series of South and Central Africa:—

1. Those in the Museum of the Geological Society of London, made by Mr. Bain and Dr. Rubidge, some of which specimens required development before I could ascertain their characters.

A. *Localities.* South Africa, Karoo Desert and its vicinity, and Graaf Reinet. A reddish-brown sandstone with fossils, amongst which the following are described by Daniel Sharpe: *Iridina* (?) *rhomboidalis*,

[1] Last year Netshayeff found some species of the above-mentioned groups in marls and sandstones of Eastern Russia, but I regret that I am unable to agree with most of his definitions, Trans. Nat. Hist. Soc. Kasan, vol. xxvii. (1894) p. 4.

[2] Palæontographica, vol. xxxix. p. 210.

Iridina (?) *ovata*, *Iridina* (?), sp., *Iridina* (?), sp., *Cyrena* (?). This sandstone, which consists of casts of lamellibranchs, resembles in external appearance and other characters the rock developed near Nishny-Novgorod in the upper horizon (B) of Permian marls and sandstones. Among these shells it was easy to recognize forms of the group *Palæomutela Inostranzewi*, but I am unable to give a more definite description, as I had to deal with casts only, though one impression, showing the irregularly striated hinge-margin so very typical of *Palæomutela*, was well preserved. I was very glad to find the original from which Sharpe made his drawing of the multidentate hinge of *Iridina* (?). These teeth are small and very irregular, though on Sharpe's drawing they appear quite regular. There are a great many small casts, undoubtedly identical with Russian forms from the same deposits, but unfortunately in a bad state of preservation. Some of these small casts belong to the groups : *Palæomutela Keyserlingi* (very like the species *P. ovalis*, m.) and *Palæomutela Murchisoni* (very like the species *P. lævis*).

B. *Locality marked.* South Africa : Karoo Desert.

Some pieces of a dark calcareous shale containing shells with external sculpture and hinge-margins preserved. From this shale I cleared off some shells, which proved to be *Palæanodonta* (*Naiadites*) *subcastor*, mihi, and *Palæomutela semilunulata*, mihi. The first is found on the Russian horizons B and C, and the second on the horizons C and D of Permian marls and sandstones near Nishny-Novgorod.

C. *Locality marked.* Karoo Series : Graaf Reinet.

The same calcareous shale containing *Palæanodonta* (*Naiadites*) *okensis*, mihi, and *Palæomutela*, cf. *Keyserlingi*, mihi, both of which forms are found on the horizons B and C of the Upper Permian marls and sandstones near Nishny-Novgorod.

D. *Locality.* Bloemkop, near Graaf Reinet. Collector, Dr. Rubidge, 1857. The rock similar to that before mentioned. On the label is written the following : *Unio* (?) with *Phyllotheca* (?), *Tylopteris*. This *Unio* I determine as *Palæanodonta* (*Naiadites*) *okensis*, mihi.

E. *Locality.* At the village of Beaufort on the right bank of the Kat River. Collected by Mr. A. G. Bain. Two pieces of greenish-grey calcareous shale with many small lamellibranchiata, some of them being described by Prof. T. Rupert Jones (Geol. Mag. 1890, p. 410) as *Cyrena* (?) *neglecta*. Perhaps some of these shells can be referred to the group of *Palæomutela Keyserlingi*, and especially to the species *subovalis*.

2. Through the kindness of Prof. T. Rupert Jones I have been able to examine six small lamellibranch-casts belonging to the Mineral Department of the British Museum (Natural History) numbered 66550, having a label which runs as follows :—'Karoo Shales, Diamond Mines, Kimberley, South Africa.' Prof. T. Rupert Jones informed me that these shales belong to the lowest horizon of the Karoo Beds at Kimberley. It was easy to recognize among these forms, especially those with a well-preserved external

sculpturing, that they belong to the group of *Palæomutela Keyserlingi* and to the species: *P.*, n. sp. aff. *orthodonta*, mihi, *P. trigonalis*, mihi, *P.*, n. sp. aff. *Golowkinskiana*. This group is found on the horizons, A, B, C, of the Upper Permian marls and sandstones of the Oka-Volga basin.

3. Prof. T. Rupert Jones has shown me a piece of greenish-grey shale containing numerous shells described by him as *Iridina* (?) *oblonga*[1] which was brought by Prof. Henry Drummond from Maramura near Lake Nyassa, Central Africa, and is now in the British Museum (Natural History). Prof. Rupert Jones considers these fossils similar to *Iridina* (?) described by Sharpe from Graaf Reinet in South Africa. They are badly preserved, exhibiting only internal casts, thus preventing a more definite determination, but probably we have here also forms representing the groups *Palæomutela Inostranzewi* and *Palæanodonta* (*Naiadites*) *Fischeri*, found on the upper horizons of the Permian marls and sandstones of the Oka-Volga basin.

4. Mr. R. Bullen Newton has been kind enough to show me the David Fraser Collection preserved in the Geological Department of the British Museum of Natural History. Among numerous lamellibranchiata from the Karoo Series (Beaufort Beds) I was enabled to determine a well-preserved specimen as *Palæomutela Murchisoni*, mihi var. (loc. Bedford, South Africa), so very characteristic of the upper horizons of the Permian marls and sandstones near Nishny-Novgorod and Gorbatoff.

From the foregoing remarks it will be seen that those forms which could be defined are from the Beaufort Beds—partly from the upper (Graaf Reinet, Bedford) and partly from the lower (Kimberley) horizons; and they belong to the genera *Palæomutela*, mihi, and *Palæanodonta*, mihi, which I consider referable to the family Anthracosidæ.

Anthracosidæ (Palæounionidæ), mihi.

Palæomutela, mihi.

1852. *Iridina* (?), Sharpe, Trans. Geol. Soc. ser. 2, vol. vii. p. 226.
1886. *Anthracosia*, Amalitsky (pars), 'Ueber das Alter d. Stufe d. Bunten Mergeln im Bassin d. Oka und Volga.'
1889. *Anthracosia*, Krotow (pars), Mém. Com. Géol. de la Russie, vol. vi. pp. 491, 511.
1890. *Iridina* (?), T. Rupert Jones, Geol. Mag. 1890, pp. 409, 553–558.
1892. *Palæomutela*, Amalitsky, Palæontographica, vol. xxxix. pp. 159–160.

Generic diagnosis. Shell equivalve, inequilateral, elongated, rhomboidal, trapezoidal, ovate, triangular. Ligament external. Hinge-margin curved, angulated, or straight, thickened below and behind umbones, covered with numerous irregular, transverse or oblique, small striæ situated on both sides of the umbo, or more rarely behind the umbo only. Muscular scars 6; adductors and pedal (retractor) muscles strong, sometimes transversely jagged or

[1] Geol. Mag. 1890, p. 557.

wrinkled; the anterior and posterior adductors are oval and large, the former being excavated posteriorly, and each surmounted by small pedal muscular scars, the anterior one of which is separated and situated under the hinge-line; behind the anterior adductor-scar is a supplementary small lunulate scar and a corresponding muscular impression in the cavity of the umbo. Pallial scar entire.

Horizon. Freshwater deposits of the Permian system of Russia and of the Karoo Series of South Africa.

The genus *Palæomutela* presents a very natural group, the numerous species of which are closely bound together by intermediate forms, notwithstanding which it has been possible to distinguish four groups among the Russian forms: 1, group of *P. Verneuili*; 2, group of *P. Keyserlingi*; 3, group of *P. Inostranzewi*; and 4, group of *P. Murchisoni*. All these four groups are also found in the Karoo Series of South Africa.

Their general characteristics are as follows:—

1. Group of *Palæomutela Verneuili*. Shell comparatively large, transverse, elongate, oval, as a general rule flattened, with tumid and slightly prominent umbones.

2. Group of *Palæomutela Inostranzewi*. Shell as a general rule smaller than that just mentioned, elongate, rhomboidal, rectangular, triangular, oval, very convex, with prominent umbones; a strong ridge extends from the umbones diagonally across the shell to the posterior inferior angle; swollen in the direction from the umbones backward towards the inferior angle, and compressed in the posterior part.

3. Group of *Palæomutela Keyserlingi*. Small shell, great variety of shapes: elongate, rectangular, oval, trigonal, convex, with moderately prominent umbones; very tumid ridge, extending from the umbones backwards to the inferior angle.

4. Group of *Palæomutela Murchisoni*. Shell rhomboidal, of various dimensions, with very prominent umbones; ridge strong, sometimes sharp, concave posteriorly, extending from the umbones diagonally across the shell to the posterior inferior angle; anterior part swollen, posterior flattened.

Forms of the Group *Palæomutela Inostranzewi*.

PALÆOMUTELA RHOMBOIDALIS, Sharpe (aff. *P. Inostranzewi*). (Pl. XII. figs. 1 and 2.)

Compare *Iridina (?) rhomboidalis*, Sharpe, Trans. Geol. Soc. ser. 2, vol. vii. (1852) p. 225, pl. xxviii. fig. 2.

1892. *Palæomutela Inostranzewi*, Amalitsky, Palæontographica, vol. xxxix. pp. 172, 173, pl. xx. figs. 21, 22, 24–28.

A broken piece of an interior cast (Bain Collection) with impression of the transversely striated hinge-margin, which is not quite rightly reproduced by Sharpe (*op. cit.* fig. 2), belongs undoubtedly to the group of *Palæomutela Inostranzewi*, and is quite identical with the numerous casts of this group found at Nishny-Novgorod in the reddish-brown sandstone of horizon B. I have not figured these

casts in my monograph, because I had in my possession shells in a better state of preservation.

Locality. South Africa: Graaf Reinet.

PALÆOMUTELA OVATA, Sharpe.

1852. *Iridina (?) ovata*, Sharpe, Trans. Geol. Soc. ser. 2, vol. vii. p. 226, pl. xxviii. figs. 3 and 4.

These fossils, and especially that represented by fig. 4 (in Trans. Geol. Soc.), belong without doubt to the group of *Palæomutela Inostranzewi*; I came to that conclusion during my recent study of the original specimen, and I am constrained to remark that the drawings given by Sharpe are too much restored and therefore far from being accurate. I find also that the specimen which served as an original for Sharpe's description of the hinge-margin of *Iridina ovata* belongs perhaps to another species (Pl. XII. fig. 3).

Locality. South Africa: Graaf Reinet.

Forms of the Group *Palæomutela Keyserlingi*.

PALÆOMUTELA, n. sp., aff. ORTHODONTA, mihi. (Pl. XII. fig. 5.)

Compare 1892. *Palæomutela orthodonta*, Amalitsky, Palæontographica, vol. xxxix. p. 169, pl. xxi. figs. 18–23, 27, 28.

The South African representative of this species differs from the Russian forms by having somewhat more prominent umbones and more anteriorly curved beaks. Although the one specimen examined proves to be closely related to *P. orthodonta*, it is necessary, for the want of further material, to consider it provisionally as a new species.

Dimensions[1]: length 12, breadth 8, depth 6; average size of Russian forms: length $11\frac{1}{2}$, breadth 7, depth 5.

In Russia *Palæomutela orthodonta* is found in the Permian marls and sandstones of the Oka-Volga basin at horizons A, B, C, and is especially characteristic of horizon C.

Locality. South Africa: Diamond mines at Kimberley.

PALÆOMUTELA TRIGONALIS, mihi. (Pl. XII. fig. 6.)

1892. *Palæomutela trigonalis*, Amalitsky, Palæontographica, vol. xxxix. p. 170, pl. xxi. figs. 15–17.

This shell differs from the Russian type, possessing somewhat more prominent and more anteriorly curved umbones. Such variations are frequent in the Russian examples of this species.

Dimensions: length 13, breadth 9, depth 6. Russian forms are very variable in size, the medium being: length 13, breadth 8, depth 7.

In Russia *Palæomutela trigonalis* is found on the upper horizons A, B, and C of the Permian marls and sandstones of the Oka-Volga basin.

Locality. South Africa: Diamond mines at Kimberley.

[1] All measurements are in millimetres.

Palæomutela aff. Golowkinskiana, mihi. (Pl. XII. fig. 7.)

Compare 1892. *Palæomutela Golowkinskiana*, Amalitsky, Palæontographica, vol. xxxix. p. 171, pl. xxi. figs. 24, 25, 29, 30.

The figure represents a young form belonging without doubt to the group of *Palæomutela Keyserlingi*. The definition of the young specimens of this group is very difficult, because with age come considerable changes. Nevertheless, it is possible to say with certainty that the specimen here referred to is very similar to the young examples of *Palæomutela Golowkinskiana*. I hope that in future more forms will be found which will enable me to unite this African shell with *P. Golowkinskiana*.

Dimensions: length 7, breadth 5, depth 4. Russian forms: length $11\frac{1}{2}$, breadth $7\frac{1}{2}$, depth 4.

P. Golowkinskiana is found in Russia in the Permian marls and sandstones of the Oka-Volga basin.

Locality. South Africa: Diamond mines at Kimberley.

Palæomutela, cf. Keyserlingi, mihi. (Pl. XII. fig. 4.)

1892. *Palæomutela Keyserlingi*, Amalitsky, Palæontographica, vol. xxxix. p. 168, pl. xxi. figs. 9–14.

The South African form of this species differs from the Russian in its larger dimensions, which makes it approach more nearly the thick and large variety of *Palæomutela orthodonta*, var. *crassa* (Palæontographica, vol. xxxix. p. 169, pl. xxi. figs. 22, 23), which belongs to the group of *Palæomutela Keyserlingi*.

In Russia *P. Keyserlingi* is found at the upper horizons (A, B, C) of the Permian marls and sandstones at Nishny-Novgorod, and is especially frequent at horizon C.

Dimensions: length 16, breadth 10, depth 8; Russian forms: length 12, breadth $7\frac{1}{2}$, depth 6.

The above-mentioned *P. orthodonta*, var. *crassa*, measures: length 16, breadth 10, depth 8.

Locality. South Africa: Beaufort Beds, at Graaf Reinet.

Palæomutela, cf. ovalis, mihi. (Pl. XII. fig. 8.)

1892. *Palæomutela ovalis*, Amalitsky, Palæontographica, vol. xxxix. p. 169, pl. xxi. fig. 8.

This badly preserved but typical internal cast bears a great similarity to the casts of *Palæomutela ovalis*, mihi. The impression of the hinge-line shows several small irregular teeth.

In Russia *Palæomutela ovalis* is found in the Upper Permian marls and sandstones of the Oka-Volga basin, on horizon C at Nishny-Novgorod, and on horizon A at the river Vetluga.

Dimensions: length 12–13, breadth $6\frac{1}{2}$–7, depth 5–6. Russian forms: length 16, breadth 10, depth 8.

Locality. South Africa: Graaf Reinet.

Forms of the Group *Palæomutela Verneuili*.

PALÆOMUTELA SEMILUNULATA, mihi. (Pl. XII. fig. 10.)

1892. *Palæomutela semilunulata*, Amalitsky, Palæontographica, vol. xxxix. p. 166, pl. xx. figs. 46–48.

This is not a typical form of the group of *Palæomutela Verneuili*. The South African representatives are quite identical with Russian specimens. *Palæomutela semilunulata* is found in Russia on horizons C and D of the Permian marls and sandstones of the Oka-Volga basin.

Dimensions: length 13, 15, 18; breadth 6, 7, $8\frac{1}{2}$; depth $2\frac{1}{2}$, 3, $3\frac{1}{2}$ (one valve). Russian forms: length 13–15; breadth 6–7; depth $2\frac{1}{2}$–3 (one valve).

Locality. South Africa: Graaf Reinet.

Forms of the Group *Palæomutela Murchisoni*.

PALÆOMUTELA MURCHISONI, mihi, var. (Pl. XIII. fig. 1.)

Palæomutela Murchisoni, Amalitsky, Palæontographica, vol. xxxix. p. 177, pl. xix. fig. 32.

The African specimen of *Palæomutela Murchisoni* differs from the Russian forms described by me in possessing a more obtusely developed ridge, which extends from the umbones backwards to the inferior-posterior angle. This distinction can only be of value when a new variety is established, but at the same time it brings this form into association with *Palæomutela plana*, which belongs also to the group of *P. Murchisoni*.

Dimensions: length 18, breadth 10; Russian forms: length 24, breadth 13.

In Russia *Palæomutela Murchisoni* is found on the upper horizon B of the Permian marls and sandstones of the Oka-Volga basin, near Nishny-Novgorod and Gorbatoff.

Locality. Karoo Beds at Bedford, South Africa.

PALÆOMUTELA PLANA, mihi. (Pl. XIII. fig. 2.)

1892. *Palæomutela plana*, Amalitsky, Palæontographica, vol. xxxix. p. 177, pl. xxii. fig. 45.

The African form of this species differs from the Russian forms only by its smaller size.

Dimensions: length 15, breadth 9; Russian forms: length 24, breadth 15.

Palæomutela plana is found in Russia on the upper horizon B of the Permian marls and sandstones of the Oka-Volga basin.

Locality. South Africa: Graaf Reinet.

PALÆOMUTELA, cf. LÆVIS, mihi. (Pl. XIII. fig. 3.)

1892. *Palæomutela lævis*, Amalitsky, Palæontographica, vol. xxxix. p. 177, pl. xx. figs. 41–43.

This badly-preserved but typical internal cast has a very great

likeness to the cast of *Palæomutela lævis* from the Russian Permian, though without more material it would be somewhat premature to identify it with the Russian forms.

Dimensions: length 4–5, breadth 2–2½; Russian forms: length 9, breadth 5.

In Russia *Palæomutela lævis* is found on the upper horizon of the Permian marls and sandstones of the Oka-Volga basin, near Gorbatoff.

Locality. South Africa: Graaf Reinet.

PALÆOMUTELA, sp. n. (Pl. XIII. fig. 4.)

Shell small, ovately oblong, convex, smooth; umbones prominent, mesial obtuse, directed slightly forwards. The dorsal margin slightly curved, anterior margin rounded, posterior margin sloping somewhat obliquely backwards. The lower border is nearly straight. All angles are rounded. The surface has fine irregular concentric striations. I think that this form is perhaps a young specimen of the group *P. Keyserlingi*. I cannot define it exactly, because sometimes the young forms of *Palæomutela* are very different from the adult stage. It is possible that this form will subsequently prove to be a young specimen of *P. trigonalis*.

Dimensions: length 7, breadth 5, depth 4.

Locality. South Africa: Diamond mines at Kimberley.

PALÆANODONTA, n. g.

1852. *Anodonta*, Forbes, Mem. Geol. Surv. Irel. Expl. Sh. 147 and 157, p. 16 (*A. Jukesii*).
1859–1863. *Anodonta*, Ludwig, Palæontographica, vols. viii., ix., xi.
1861. *Anodonta*, Geinitz, 'Dyas.'
1868–1878. *Naiadites*, Dawson, pars, 'Acadian Geology,' 2nd and 3rd eds. pp. 204–205.[1]
1892. *Naiadites*, Amalitsky, Palæontographica, vol. xxxix.
1894. *Naiadites*, Netshayeff, 'Die Fauna der permischen Ablagerungen des östlichen Theils des europäischen Russlands.'
1894. *Carbonicola*, Wheelton Hind (pars: only edentulous forms), Palæont. Soc. vol. xlvi.

Diagnosis. Shell equivalve, inequilateral, elongated or oval, unioniform, smooth. Ligament external, situated behind the umbones. Hinge-margin toothless, curved, angulated or straight, sometimes thickened. The scars of the adductors are strong, oval, or elongated; the small scar of the pedal muscle is separated from the anterior adductor and situated under the hinge-line; very rarely a supplementary small lunate scar is situated behind the anterior scar of the adductor. Pallial scar entire. Valves closed.

The type is *Palæanodonta Castor*, Eichw., sp. For synonymy, etc., see my paper, 'Ueber die Anthracosien der Permformation Russlands,' Palæontographica, vol. xxxix. (1892) p. 192, pl. xxii. figs. 40–43.

[1] A discussion of the synonymy of *Naiadites*, Dawson, which is contained in Dr. Wheelton Hind's papers, Quart. Journ. Geol. Soc. vol. xlix. (1893) and vol. l. (1894), will be published in a subsequent memoir.

Horizons.—Freshwater deposits of the Devonian, Carboniferous, and Permian systems.

In studying the Carboniferous and Permian Anthracosidæ in 1892, I found it impossible to retain the Palæozoic forms described by Forbes, Ludwig, and Geinitz as *Anodonta*, but included them under the generic name of *Naiadites*, Dawson. My reason for adopting this was that Dawson, under the term *Naiadites*, described and figured six forms ('Acadian Geology,' 2nd & 3rd eds.),[1] which he named:—*N.* (*Anthracoptera*) *carbonaria*, *N.* (*Anthracomya*) *elongata*, *N.* (*Anthracoptera*) *lævis*, *N. arenacea*, *N. ovalis*, *N. angulata*. Therefore we see that Dawson's *Naiadites* includes three groups of organisms: *Modiola*-like *Anthracomya*, Salter (1861), and *Anthracoptera*, Salter (1863), and *Anodonta*-like properly *Naiadites* (*N. arenacea*, *N. ovalis*, *N. angulata*). Salter having already established the generic names *Anthracoptera* and *Anthracomya* for the first two groups, I substituted *Naiadites* only for the last—that is, for the *Anodonta*-like shells. But Dawson, according to Dr. Wheelton Hind,[2] and in a more recent paper,[3] considers it best to drop out Salter's genus *Anthracoptera* (1863) and replace it by *Naiadites*. The third group, the *Anodonta*-like shells (*N. arenacea*, *N. ovalis*, *N. angulata*), which at first he held to be true *Naiadites*, he considers now as follows:—the two species *N. arenacea* and *N. ovalis* he refers to *Anthracomya*, giving them different diagnoses and drawings[4] from those that he had previously given, and one species (*N. angulata*) he refers to *Anthracosia*. In consequence of this the *Anodonta*-like forms, which I described in 1892 as '*Naiadites*, Dawson,' remain now without a generic name, so that I venture to establish for them the new genus *Palæanodonta*. This differs from *Anthracomya*, Salter, (1) by having equivalve shells always closed at both extremities; (2) by having a narrow posterior end (in typical forms); (3) by its curved, angulated (seldom straight) hinge-line; (4) by the disposition and shape of the muscular scars being quite similar to those in *Carbonicola*, M'Coy, *Anthracosia*, King, or *Palæomutela*, mihi.

PALÆANODONTA OKENSIS, mihi. (Pl. XIII. fig. 6.)

1892. *Naiadites okensis*, Amalitsky, Palæontographica, vol. xxxix. p. 193, pl. xxii. figs. 26–29.

This shell agrees completely with the diagnosis and the original specimens themselves of this species, which are in my possession, from the Permian marls and sandstones at Nishny-Novgorod, horizon C.

Dimensions: length 17, breadth 18; Russian forms: length 20, breadth 10–11.

Locality. South Africa: Bloemkop, near Graaf Reinet.

[1] See Pl. XIII. figs. 7–10, 12, 14.
[2] Quart. Journ. Geol. Soc. vol. l. (1894) p. 437.
[3] Canadian Record of Science, Oct. 1894, 'Rev. of the Bivalve Mollusca of the Coal-Formation of Nova Scotia.'
[4] See Pl. XIII. figs. 11 and 13.

PALÆANODONTA SUBCASTOR, mihi. (Pl. XIII. fig. 5.)

1892. *Naiadites subcastor*, Amalitsky, Palæontographica, vol. xxxix. p. 191, pl. xxii. figs. 30–33.

1894. *Naiadites subcastor*, Netshayeff, 'Die Fauna der permischen Ablagerungen des östlichen Theiles des europäischen Russlands.'

The South African shells determined as this species conform fully to the diagnosis of *Palæanodonta subcastor*, and are especially like the forms found near Gorbatoff, Oka river, on horizon B of the Permian marls and sandstones of the Oka-Volga basin.

This species occurs on all the horizons of the Permian marls and sandstones of Eastern Russia.

Dimensions: length 21, breadth 10, depth 8; Russian forms: length 19, breadth 10, depth 6.

Locality. South Africa: Graaf Reinet.

EXPLANATION OF THE PLATES.

PLATE XII.

Fig. 1. *Palæomutela rhomboidalis*, Sharpe, Graaf Reinet. 1 *a*, lateral view; 1 *b*, showing striated hinge-margin. Sharpe's original specimen.
2 *a*, *b*. *Palæomutela rhomboidalis*, Sharpe. Bloemkop.
3. *Palæomutela*, sp. Graaf Reinet. The original specimen for Sharpe's description of the hinge of *Iridina* (?) *ovata*. 3 *a*, natural size; 3 *b*, enlarged, and showing transversely-striated hinge-margin.
4 *a*, 4 *b*. *Palæomutela*, cf. *Keyserlingi*, mihi. Graaf Reinet.
5. *Palæomutela*, n. sp., aff. *orthodonta*, mihi. Diamond mines at Kimberley. 5 *a*, showing the external view; 5 *b*, showing badly-preserved hinge-line.
6 *a–f*. *Palæomutela trigonalis*, mihi. Diamond mines at Kimberley.
7 *a–e*. *Palæomutela*, n. sp., aff. *Golowkinskiana*, mihi. Diamond mines at Kimberley.
8. *Palæomutela*, cf. *ovalis*, mihi. Graaf Reinet.
9. *Palæomutela*, sp. Diamond mines at Kimberley.
10. *Palæomutela semilunulata*, mihi. Graaf Reinet. 10 *a–d*, external view; 10 *c'*, showing the hinge-margin; 10 *d'*, hinge-margin, natural size; 10 *d''*, enlarged; 10 *d'''*, hinge-margin from above.

PLATE XIII.

Fig. 1. *Palæomutela Murchisoni*, mihi, var. Bedford.
2. *Palæomutela plana*, mihi. Graaf Reinet.
3. *Palæomutela*, cf. *lævis*, mihi. Graaf Reinet.
4. *Palæomutela*, sp. n. Diamond mines at Kimberley. 4 *a*, *b*, lateral view; 4 *c*, from above.
5. *Palæanodonta subcastor*, mihi. 5 *a*, lateral view; 5 *b*, hinge-margin. Graaf Reinet.
6. *Palæanodonta okensis*, mihi. 6 *a*, *b*, from Graaf Reinet; 6 *c*, from Bloemkop.

Copies of Drawings of *Naiadites*, Dawson.

Fig. 7. *Naiadites* (*Anthracoptera*) *carbonaria*, Dawson ('Acadian Geol.' 2nd ed. p. 204, fig. 42).
8. *Naiadites* (*Anthracomya*) *elongata*, Dawson (*ibid.* fig. 43).
9. *Naiadites* (*Anthracoptera*) *lævis*, Dawson (*ibid.* fig. 44).
10. *Naiadites arenacea*, Dawson (*ibid.* fig. 45).

Fig. 11. *Anthracomya arenacea*, figured by Dawson as a synonym of the above-mentioned *Naiadites arenacea* ('Review of the Bivalve Mollusca of the Coal-Form. of N. Scotia,' p. 12, fig. 10[1]).

12. *Naiadites ovalis*, Dawson ('Acad. Geol.' 2nd and 3rd eds. p. 205, and Quart. Journ. Geol. Soc. vol. x. 1854, p. 39, fig. 24).

13. *Anthracomya ovalis*, figured by Dawson ('Rev. of the Bivalve Mollusca,' etc. p. 13, fig. 11) as a synonym of the above-mentioned *Naiadites ovalis*, Dawson.

14. *Naiadites angulata*, Dawson, 'Acadian Geology,' 2nd ed. p. 204, fig. 46.

Discussion.

The President bore testimony to the value and importance of the work carried on by Prof. and Mme. Amalitsky in describing and figuring the various species of lamellibranchs from the Coal Measures and the Permo-Carboniferous strata of Russia and elsewhere. The present paper dealing with the African species was the result of several months' work on the British Museum Collection and in that of the Geological Society. He trusted that careful attention would be given to the question of synonymy, and pointed to the valuable list drawn up by Mr. E. T. Newton, F.R.S., in the Quarterly Journal for 1894, attached to Dr. Wheelton Hind's paper.

Prof. H. G. Seeley stated that in St. Petersburg he had gathered from Dr. Karpinsky that the palæontological evidence was slender for determining the age of the Permian deposit which yields *Rhopalodon* and *Deuterosaurus*. Beneath that deposit there is a bed termed 'Permo-Carboniferous,' which also yields a few anomodont bones. And somewhat higher in the series are fish-remains of the type of *Acrolepis*, common to Permian and Trias. Many of the bones that he had studied were from a marine bed full of *Modiolopsis Pallasi* and a species of *Terebratula*.

The superficial resemblance in dentition between the Russian Permian reptiles and those of South Africa was misleading; for while both belong to the therosuchia, the African theriodontia all have the coronoid process of the dentary bone much elevated, and the hard palate terminates in a transverse edge behind which the palato-nares descend; while in the Russian deuterosauria the coronoid process is not elevated, and the palato-nares open as ovate vacuities, as in the palate of nothosaurs and plesiosaurs.

It was therefore remarkable to find that the freshwater shells of the Karoo rocks were determined as identical with those of the Permian of Russia; notwithstanding the well-known persistence of freshwater shells in geological time, with little change. The Karoo Beds are of immense thickness, and their outcrop covers about 70 miles of breadth. About 20 miles north of the base, following the dip, the one example of shells occurred which was known in the Colony, at the base of beds yielding *Pareiasaurus*. He thought that all the African beds which contain anomodontia are probably Permian, and the upper beds of the Karoo System

[1] Canadian Record of Science, October, 1894.

were so classed in his account of the theriodontia, communicated to the Royal Society. There are traces of coal at the base of the Karoo system, more in the middle and most at the top, where the Indian genera *Tæniopteris* and others are found. Above these are the Stormberg Beds, which he regarded as Trias, which yield dinosaurian reptiles (saurischia) closely allied to those of the Trias of Europe. He thought it an advantage to have evidence from an invertebrate group of animals upon the age of the beds; and the results represented patient and careful work.

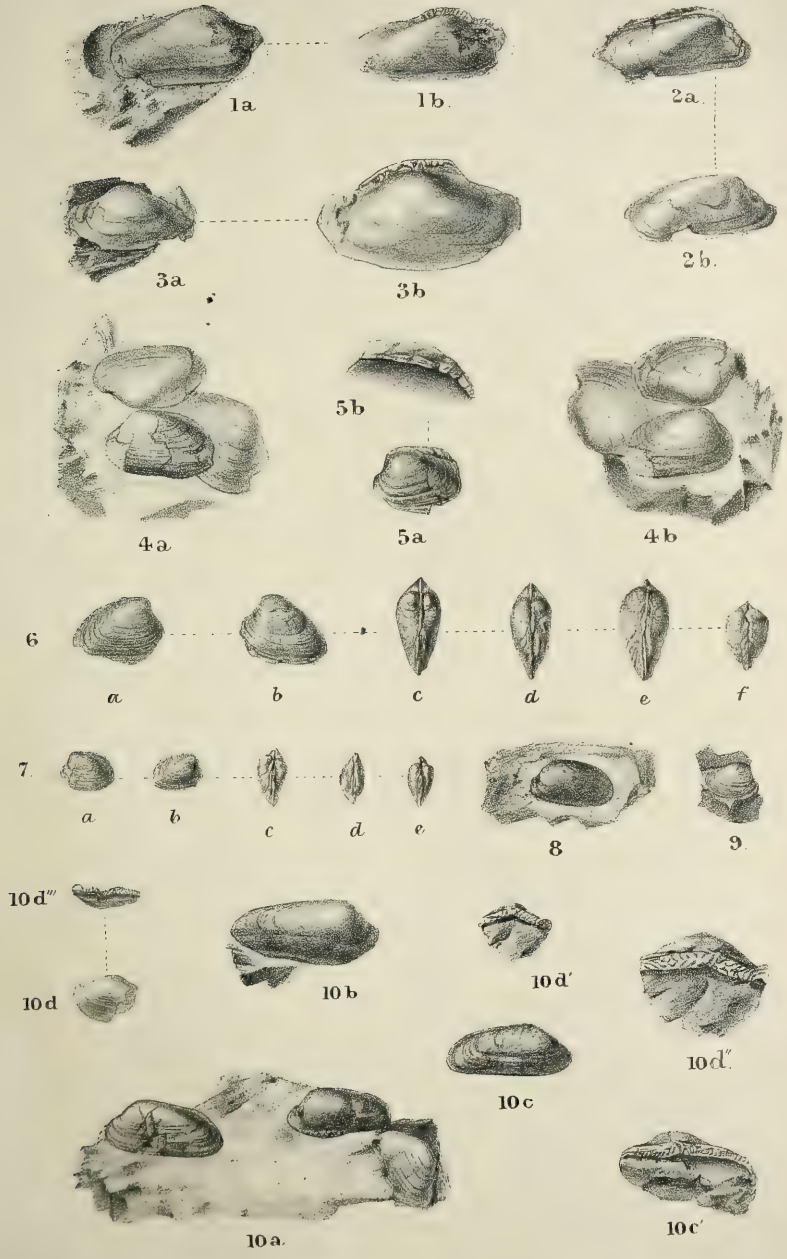
Dr. Blanford said that the Karoo series of South Africa comprised beds ranging in age from Carboniferous to Middle Mesozoic, probably Jurassic; and Prof. Green, in the discussion on his paper in the Society's Journal for 1888, had found himself unable to determine what the Beaufort Beds were. The flora found in the lower stages of the Karoo Beds of South Africa, like that in the Lower Gondwánas of India, and that in the Newcastle Beds of Australia, differed so completely from that found in strata of the same age (Carboniferous and Permian) in Europe as to indicate that the Northern and Southern land-regions throughout Upper Palæozoic times were completely isolated from each other. If, then, the mollusca described by Dr. Amalitsky came from beds of Permian age in Russia and South Africa, and were identical or closely allied, it would be a question whether those mollusca were not marine or estuarine rather than freshwater. No traces of any similar bivalves had been found in the Gondwána system of India, the beds of which, on account of their economic importance, had been very thoroughly searched for fossils.

Prof. T. Rupert Jones said that the Society was to be congratulated on receiving an account of Prof. Amalitsky's researches on these African and Russian fossils—whether of Triassic, Permian, or Permo-Carboniferous age. The Author was careful in speaking of their homotaxis rather than contemporaneity. Those from South Africa had come from places far apart—namely, Graaf Reinet, Kat River, Kimberley, and the north-western border of Lake Nyassa. He thought it possible that they may have been of estuarine (or salt-lake) rather than of river-origin. He particularly alluded to the excellent and exact drawings of the most noteworthy of these little fossils, made by Mme. Amalitsky for comparison with those of Russia.

Mr. E. T. Newton made some remarks on the synonymy of *Naiadites*.

Mr. R. B. Newton thought that there should be no difficulty in accepting the Author's new generic name of *Palæanodonta* for the three forms described by Sir J. W. Dawson in 1860 as *Naiadites arenacea*, *N. ovalis*, and *N. angulata*, which differ so widely from the type of the genus (*N. carbonaria*), and which had also been wrongly referred by Dr. Wheelton Hind (1894) to *Anthracomya* and *Carbonicola*. The Author's synonymy of this new genus would be better explained by the introduction of the word *pars* after '*Naiadites*, Dawson, 1860.'

Mr. G. F. Harris observed that that portion of the paper which



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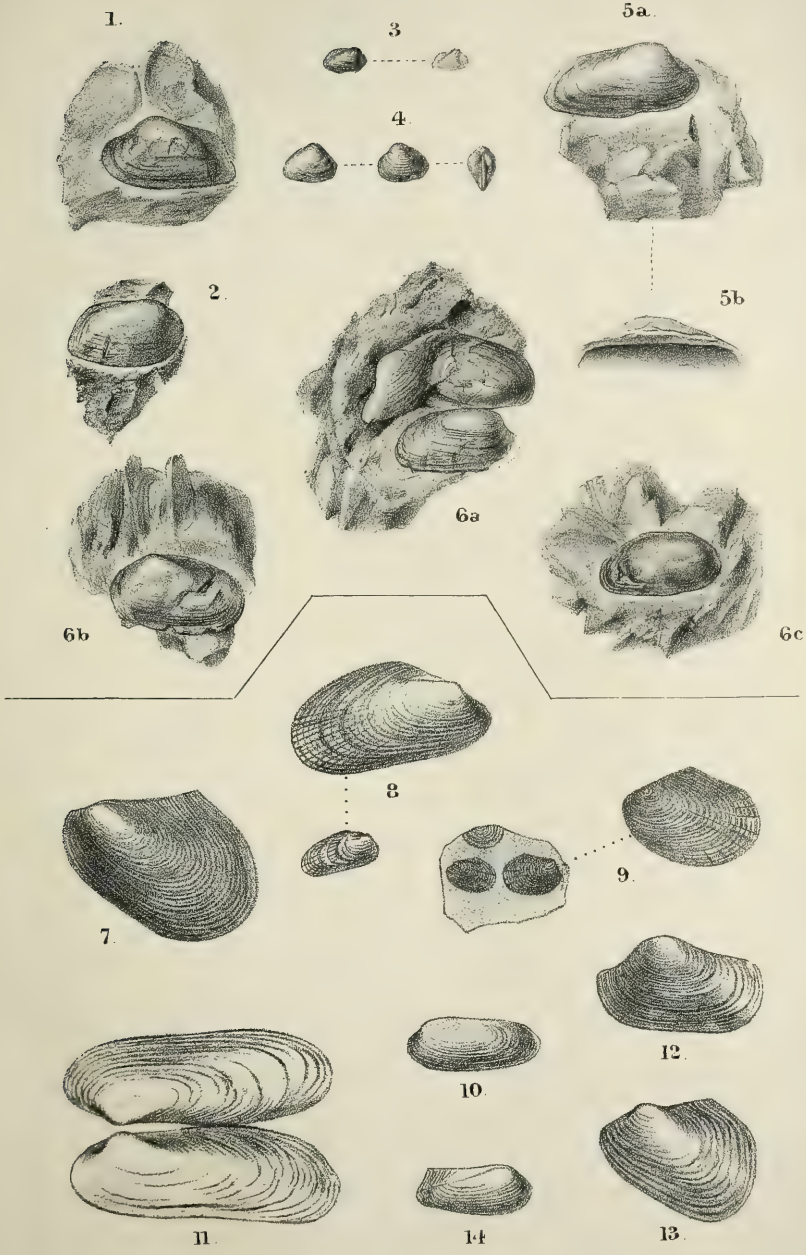
PALÆOMUTELA.



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PALÆOMUTELA AND PALÆANODONTA
AND REPRODUCTIONS OF NAIADITES, ETC.

dealt with correlation depended in a great measure on the correctness of the Author's identification with the Zechstein of the Russian freshwater beds alluded to. It would have been better, perhaps, to have omitted the evidence afforded by the vertebrata, seeing that Russian geologists were not in accord as to the precise age of the deposits in which these occurred. The excellent work done by Prof. Amalitsky with reference to the genera *Palæomutela* and *Palæanodonta*, and the successful manner in which he had shown that Russian freshwater lamellibranchiata were represented, almost specifically, in the Karoo Beds of Africa, were points for congratulation. It might be remarked, however, that the Author's views as to what constituted a species in the Anthracosidæ and their allies were rather broad—a circumstance which might have assisted him in recognizing a closer relationship between the European and African mollusca alluded to than would otherwise have been the case. The Author had been extremely careful in drawing up the generic synonymy of certain forms described by Sir J. W. Dawson, and this paper would set at rest many hitherto doubtful matters in that connexion. Altogether, it was a very valuable and important communication.

26. Supplementary Notes *on the* Systematic Position *of the* Trilobites.

By Henry M. Bernard, Esq., M.A. Cantab., F.L.S., F.Z.S. (Communicated by Dr. Henry Woodward, F.R.S., P.G.S. Read April 24th, 1895.)

Since I had the honour of reading a paper on this subject before the Geological Society (printed in this Journal, vol. l. 1894, p. 411) two other papers have appeared in America, giving further details as to the appendages and structure of *Triarthrus*.[1] Both papers are by Dr. C. E. Beecher. The earlier, describing the pygidial limbs, appeared in time to be briefly mentioned in a footnote in my own paper just referred to. The more recent has but now appeared, and gives an account of the ventral structure of *Triarthrus*. These two papers seem to me to contain matter of perhaps even greater morphological interest than the discovery of the antennæ.

The Metastoma.—Taking the new evidence, not in the order of its appearance, but in the order of the parts referred to, the metastoma, 'now revealed for the first time,' is described and figured by Dr. Beecher as a small, convex, arcuate plate just posterior to the extremity of the hypostoma. A small arcuate plate projecting backwards, as shown in Dr. Beecher's figures, is the exact form that the labium or lower border of the mouth must have assumed, when the first segment of the hypothetical annelid ancestor bent round so that the mouth opened posteriorly for the new method of feeding. But such a metastoma, as I have already argued, would be a disadvantage: it would form a barrier in the way of food being pushed into the mouth by the 'gnathobases.' In *Apus* we accordingly find the metastoma modified into two lobes placed laterally and squeezed in between the mandibles and maxillæ. This arrangement leaves the middle passage to the mouth open, while it prevents food-particles from escaping laterally between the biting-limbs. In *Triarthrus* we find the first stages of this modification; the primitive metastoma is not yet obliterated in the middle line, but the lateral lobes are beginning to develop.

Again, in the position of the labium, in front of, or at least in a line with[2] the jaw-pieces of the second pair of appendages, *Triarthrus* has retained a very primitive feature. It is obvious that, on the bending round of the first segment for the pushing of food into the mouth, no pair of parapodia would at first be in exact position

[1] 'The Appendages of the Pygidium of *Triarthrus*,' Am. Jour. Sci. ser. 3, vol. xlvii. (1894) p. 298; and 'Further Observations on the Ventral Structure of *Triarthrus*,' American Geologist, vol. xv. (1895) p. 91.

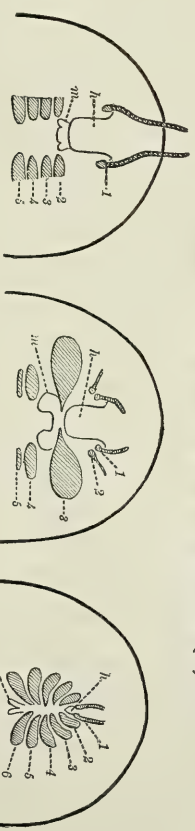
[2] I see no reason for doubting that the relative position of these parts as shown in Dr. Beecher's figures is the natural one. The metastoma and the limbs inserted near it could not well move apart without tearing the cuticle. I do not think that the chitin would be likely to stretch very much, as Dr. Beecher suggests, except in the sense of smoothing out folds. But such a stretching would, I think, reveal the true relations of the parts to one another.

to function as jaws. The appendages of the 2nd segment, which would be the nearest to the mouth in its new position, must still at first have been behind the labium.

In *Apus* we find a high degree of specialization; the greatly developed lateral lobes of the labium have grown backward so as to overlap posteriorly the jaw-pieces of the third pair of appendages, which are developed as enormous mandibles.

In *Limulus* we find a still further specialization. The labial lobes have been forced back still farther, and appear as two small appendages behind the jaw-pieces of the sixth pair of appendages. Lastly, the large metastoma of the Eurypterids is probably a further adaptation of the same labial lobes situated also behind the sixth pair of appendages.

We can thus trace through *Triarthrus*, *Apus*, and *Limulus* A, B, C, *m*) the gradual modification of the labium from its primitive condition as a ridge-like posterior border of the mouth, such as the 'bent annelid' theory demands, into the pair of specialized and enigmatical lobes such as is found in the last-named animal. We can also trace equally clearly through the same series the gradual translocation of the labium, or rather of its lateral lobes, as they travelled backwards from their primitive position in front of the second pair of appendages to their extreme position behind the sixth pair.



Diagrammatic representation of the relations of the mouth-parts of Triarthrus (*A*), *of* Apus (*B*), *and of* Limulus (*C*).

1, 2, 3, 4, 5, 6. The first to sixth appendages or portions of appendages.
h=hypostoma or labrum; *m*=metastoma or labium.
The parts are spread out for the sake of clearness.

The Mouth-formula.—The original similarity of the limbs of the head and of the trunk, which the annelidan theory demands, is still found in *Triarthrus*.

Passing by the first pair, each of which was probably from the first nothing more than the cirrus of a notopodium, as is frequently the case in the chætopods, we find all the following appendages (excluding those of the pygidium) structurally alike.

This is no longer the case in *Apus*. But, as I have endeavoured to show, the conditions there found can be traced in detail from such a hypothetical primitive condition. The head-limbs, in developing their jaw-pieces, did not require the dorsal portions of the parapodia; these, however, in some cases persist as vestiges. On the trunk, on the other hand, the dorsal portions of the parapodia were most needed and developed as locomotory appendages.

Here again, then, in this primitive homogeneity of the head- and trunk-appendages, *Triarthrus* ranks far below *Apus*, in which certain of the appendages near the mouth are already structurally modified for co-ordinated action as jaws and maxillæ, and accordingly form a group apart from the thoracic limbs.

Dr. Beecher's figures seem to show a tendency in the jaw-pieces of the head-limbs of *Triarthrus* to become more and more powerful as we recede from the mouth; those of the fifth pair appear as the largest (*A*, p. 353). This cannot be considered as a mere accident, inasmuch as we find the same gradual increase in the size of the jaws distinctly marked in *Limulus* (*C*, p. 353), and enormously pronounced in *Eurypterus*. In these two animals the maximum of size is reached in the sixth pair of appendages. According to the browsing annelid theory, the pair of jaw-pieces nearest the mouth (that is, of the second appendages) would, one would think, develop to be the largest. Yet in no case does this happen. It is, however, typical of many chætopods that the first pair of appendages is reduced to little more than the cirrus of the notopodium; the second pair, complete as far as form goes, is often small, while the third and following pairs increase in size until a maximum is reached. It is obvious, then, that if such a chætopod took to browsing in the manner described, the limbs which were first ranged on each side of the mouth would necessarily show this gradual increase in size.

On this primitive condition the arrangement of the jaws in *Apus* (*B*, p. 353) is a striking advance in specialization. We there find that the smaller jaw-pieces of the second pair of appendages were allowed to atrophy in favour of the larger and more powerful jaw-pieces of the third appendages, which became true biting-jaws working within the mouth-aperture—that is, between the labrum and the labial lobes. This arrangement amounted to a practical monopoly of the mouth-aperture by a single pair of mandibles; while the following pairs, divorced from any close connexion with the mouth, and being, compared with the mandibles, of secondary importance, show either no great specialization or even degeneration (*B*, 5, p. 353).

This striking specialization of the mouth-parts found in *Apus* must have had some advantages over the simpler and more primitive (annelidan) condition found in *Triarthrus* and *Limulus*. It is not improbable that the single pair of highly specialized jaws, their cutting edges working between the labrum and the labium—that is, well within the mouth-aperture—are in many respects far more efficient instruments for alimentation on which growth and multi-

plication ultimately depend than a number of pairs of jaws grouped around, that is, necessarily in less close association with, the mouth. Another advantage, however, might be found in that the atrophy of the jaw-pieces of the second pair of appendages would release their dorsal branches to become specialized as sensory feelers. Although this latter specialization can hardly be said to have taken place in *Apus*, we know, from the great development of the second antennæ in the higher crustacea, that this pair of appendages, rejected as jaws, have become most efficient sensory organs.

Triarthrus represents the primitive type of mouth-formula, which is handed on somewhat specialized to the other merostomata. *Apus*, however, branched off and by developing the jaw-pieces of the third pair of appendages as specialized mandibles started the type of mouth-parts belonging to the crustacea proper. That the mouth-formula of *Apus* is the origin of the mouth-formulæ of the higher crustacea admits of little doubt when the other primitive features in its organization are taken into account.

The Appendages of the Trunk and Pygidium.—Burmeister,[1] in his restoration of the trilobite, figured the under-surface as provided with two complete series of many-lobed phyllopodan appendages, which, however, did not extend to the rudimentary pygidial segments. Actual discovery of portions of filamentous limbs apparently finally disposed of Burmeister's restoration. It was obvious, however, that if the trilobites were related to *Apus*, the limbs of the fused rudimentary pygidial segments might have been phyllopodan, as they are in *Limulus*. On the other hand, Walcott's restoration, partly based upon Hall's discovery of the underside of *Asaphus*, showed them to be filamentous. On the whole, then, while firmly believing that the trilobites must have at one time had phyllopodan appendages, I was inclined to believe that the limbs in the trilobites, being filamentous in the developed segments, might also appear as such from the first, it not being necessary to assume that they passed through any phyllopodan stage in their ontogenetic development. After all, Burmeister's restoration has been so far justified that one trilobite[2] is now known to have had phyllopodan limbs, not in the thorax, where he placed them, but in the pygidial segments, where he left them out.

This discovery fully justifies the explanation which I have offered of the morphology of the posterior region of *Apus*, and the homologizing of that region with the pygidial region in the trilobites. In both cases we have a fixation of larval conditions. We now know, then, that the common racial form of both *Apus* and the trilobites possessed phyllopodan appendages, which in the former

[1] 'Die Organisation der Trilobiten aus ihren lebenden Verwandten entwickelt,' Berlin, 1843; Engl. transl. edited by T. Bell & Edw. Forbes, Ray Soc. 1846.

[2] Since this was written Dr. Beecher has discovered that the pygidial limbs of *Trinucleus* show essentially the same characters; see Am. Journ. Sci. ser. 3, vol. xlix. (1895) p. 307.

case, while persisting as swimming-plates, are anteriorly adapted for clinging to weeds, and in the latter case were early changed into filamentous crawling-legs.

In my former paper I suggested two possible genealogies, one in which the trilobites appeared as offshoots specialized for a creeping manner of life, from the main crustacean stem, and the other in which *Apus* and the higher crustacea are deduced from the trilobites by a secondary loss of pleuræ along the trunk-segments. The persistence in *Apus* of cylindrical trunk-segments but loosely bound together inclined me to pronounce strongly in favour of the former. This choice is now amply justified. Not only in the form of the segments, but in their number and in the character of the appendages, *Apus* stands far below the trilobites. *Apus*, in spite of the specialization of its mouth-parts, in the possession of traces of over sixty cylindrical body-segments, and of its but slightly modified leaf-like limbs, is clearly in the direct line of descent between the original annelidan ancestor of the whole group and the higher crustacea. The trilobites, on the other hand, while retaining the homogeneity of the head and trunk-limbs, and other primitive annelidan characters which have been lost in *Apus*, are yet specialized by the great reduction in the number of body-segments, by the development on every segment of large pleuræ, and by the early modification of the phyllopodan appendages.

The trilobites, therefore (as exemplified by *Triarthrus*), in spite of their extremely primitive mouth-formula, do not stand in the direct line of descent of the crustacea, but are lateral offshoots, specialized for a creeping manner of life.

Specialization of the Limbs.—In the modification of the original phyllopodan appendages it is the endopodites in both *Apus* and the trilobites which are most modified. The exopodite, which I think was the original notopodial cirrus, retains in both cases its phyllopodan specialization as a swimming-organ.

Triarthrus possessed the gnathobases on the trunk-limbs, somewhat as we find in *Apus*. This, as I endeavoured to show in my former paper, was rendered highly probable by an examination of Walcott's results,[1] and by a comparison of his sections of *Calymene* with sections of *Apus*. This point is now set at rest. The phyllopodan limbs of the larval segments, in developing into walking-legs, retained throughout their whole length the gnathobases which, round the mouth, become the jaws. Dr. Beecher has accordingly given an emended diagrammatic section—emended, that is, from Walcott's well-known figure in his classical paper just quoted. If I might be allowed to suggest a further emendation, it would be in the direction of making the line of insertion of the limb much longer transversely. Walcott's sagittal sections, compared with sagittal sections of *Apus*, appear to me to leave no doubt that the

[1] 'The Trilobite: New and Old Evidence relating to its Organization,' Bull. Mus. Comp. Zool. Harvard, vol. viii. 1880–81.

dorsal skin of the leg passed proximally into the under surface of the pleura, and, on the other hand, that the gnathobase was joined to the body somewhat farther in towards the median line.

In this connexion it is impossible to avoid noticing the remarkable length and filiform character of these gnathobases on the trunk-limbs of *Triarthrus*. If the appearances are not deceptive, it looks as if some differentiation had already taken place between the jaw-pieces of the limbs nearer the mouth and those of the limbs farther off; this supposition being further justified by the fusion of a certain number of segments to form a head-region. The filiform character of the gnathobases of the thorax requires further elucidation.

There appear to be no traces of gills on the limbs of *Triarthrus*. Their absence seems to allow of the exopodites being attached higher up on the limb than is the case in *Apus*, in which a well-developed gill persists. In *Limulus* both gills and exopodites have vanished from the walking-limbs, except from the last pair, which have rudimentary exopodites. But in this case the gill portions of the phyllopodan abdominal (pygidial) appendages are greatly specialized. It is possible that, when the pygidial or the transitional limbs of *Triarthrus* are further unravelled, gills may be discovered. This expectation is justified by the presence of larval phyllopodan limbs at the extreme end of the body, indistinguishable, so far as their ventral edges go, from the larval limbs of *Apus*, which we know had gills inserted on their dorsal edges. It is true that gills are not shown on the limbs figured by Claus and copied by Beecher,[1] but they are quite distinct on the smallest rudimentary limb on a specimen of *Apus productus* ('Apodidæ,' fig. 10). The presence of typical phyllopodan appendages necessitates the assumption that gills have somewhere to be taken into account. It seems hardly likely that they should have completely vanished along the whole length of the body. Somewhere in the series between the developed crawling-legs and the larval phyllopodan limbs, gills of some kind, however rudimentary, must surely have existed. In some trilobites they may have been better developed than in *Triarthrus*, and Walcott's interpretation of his sections is, in this respect, by no means necessarily incorrect.

Former presence of Setæ on the Appendages.—The appendages of *Triarthrus* show very distinct traces of the former presence of setæ. Those, however, which are personally of most interest to me are figured by Dr. Beecher as tufts of stiff setæ on the dorsal edges of the exopodites, near their attachments to the coxopodite on the 4th and 5th head-limbs. In view of the very primitive annelidan characters of the limbs above insisted upon, these setæ, allowing for some shiftings of position, may well be the derivatives of the parapodial setæ of the chætopodan ancestral form. In my endeavours to

[1] 'The Appendages of the Pygidium of *Triarthrus*,' Am. Journ. Sci. ser. 3, vol. xlvii. (1894) pl. vii. fig. 4.

deduce *Apus* from a chætopod I assumed the former presence of such setæ, and, finding the shell-gland opening on the dorsal branch of the 5th head-limb, I suggested that this gland might be a derivative of a setiparous gland. Here is not the place to enter upon this rather difficult discussion, especially as I have gone into the subject at length elsewhere.[1] I will only add that the discovery of tufts of setæ on the limbs of *Triarthrus*, which are in many respects very primitive, in practically the very spot where, in *Apus*, I assumed their former presence, may, I think, fairly be claimed as one more slight confirmation of my general argument.

Head-Segments.—Dr. Beecher corrects me in my suggestion that *Triarthrus* may have had only four segments in its head-region. There are five pairs of limbs apparently attached under the head-shield. This would, however, make no difference to the general drift of my argument that the gradual building-up of the crustacean head can be traced in the trilobites. The gradual incorporation of body-segments, probably associated with the specialization and co-ordinated movements of mouth-limbs, undoubtedly took place, and it did not stop with the trilobites, but continued till in *Limulus* and the Eurypterids six segments fused to form a head-region. In the case of *Limulus* the whole of the rest of the body corresponds to a pygidium with persistent phyllopodan appendages. In the Eurypterids, on the other hand, the posterior segments remained free, as they were also in the earliest known trilobites (*Olenellus*).

Phylogenetic Conclusions.—Summing up our comparison of the new and important facts described by Dr. Beecher with the known conditions of *Apus*, we find that the crustacea can now be linked, step by step, with the chætopod annelids. The line of development is practically that which I sketched in my former paper, but we are now in a position to supplement that scheme by additional details which bring it still closer to the actual order.

The common ancestor of *Apus* and *Triarthrus* had a many-segmented cylindrical body, the former still showing traces of more than sixty segments. A large prostomium bent round towards the ventral surface, so that the mouth opened downwards and backwards; each segment except the first was provided with a pair of swimming leaf-like appendages, richly provided with setæ; each such appendage carried on its dorsal edge a gill and an exopodite. The appendages of the first segment were simply cirrus-like, and they pointed downwards on each side of the ventrally-placed prostomium. Such an animal is a typical chætopod annelid, with the first segment bent round ventrally. We gather from later specializations that this bending was for the purpose of using the parapodia nearest the mouth to push in the food.

These free-swimming browsing annelids early developed pleuræ on a few of the most anterior segments. Such pleuræ were formed

[1] 'Comparative Morphology of the Galeodidæ,' § Excretion. Read before the Linnean Society, February 1895. (In the press.)

before any great specialization of the mouth-limbs took place. All we can safely postulate with regard to these pleuræ, judging again from later specializations, is that they were protective, and perhaps originally only for the protection of the larvæ with but few segments; this might account for their limitation in many subsequent forms to the head-segments alone. In the meantime the body was shortening by the fixation, at its posterior end, of a certain number of segments in a rudimentary condition.

From these primitive crustacean-annelids a group branched off, their specialization being the continuation of the original head-pleuræ along the whole length of the body. This was in adaptation to a crawling manner of life, the limbs on the developed segments becoming modified into legs. These, the trilobites, were, in fact, as I ventured to call them three years ago, browsing armoured annelids. In direct line with these arose *Limulus* and the Eurypterids, the last-named being specialized by the secondary degeneration of the pleuræ.

The main branch developed the pleuræ primarily on five segments only, where they formed a head-shield, which grew back as a fold over the posterior segments. The trunk-segments remained cylindrical, and the trunk-limbs persisted as swimming-plates. The limbs near the mouth, on the other hand, became greatly specialized, the most important modification being the rejection of the second appendages as jaws, leaving them free to become sensory feelers, and the great development of the jaw-pieces of the third pair as mandibles, working well within the mouth-aperture. The process of shortening the body by the fixation of a still larger number of the inherited body-segments in a larval condition became more and more marked. Such a development answers to *Apus*, from which animal all the higher crustacea can be deduced.

Discussion.

The President remarked that Mr. Bernard's paper dealt with some additional points of structure observed in certain trilobites recently described by Dr. C. E. Beecher, and he suggested that, in all probability, the very small, rudimentary, paired appendages, attached to the posterior segments in *Triarthrus* and *Trinucleus*, indeed even the fringes of setæ on the exopodites generally (like the similar setaceous appendages in *Mysis*), may have served as branchial appendages. Again, although there does not appear to have been a pair of very large and specialized jaws in the trilobites, as seen in *Apus*, we may feel certain that 2 or 3 pairs of the anterior appendages in trilobites had already been differentiated to serve as simple jaw-feet.

He referred to the Author's important observation made in his former paper as bearing on the resemblance of *Apus* to trilobites—namely, that at a certain stage a number of the hinder segments in both had become fixed as a series of not fully developed and still rudimentary segments.

Judging from the occurrence of *Protocaris Marshii* (an early *Apus*) with *Olenellus* in Lower Cambrian rocks, the ancestors of *Apus* must have been contemporary with those of the trilobites, and such a form as *Protocaris* may have given origin to the Phyllocarida of the Palæozoic rocks, which they somewhat resemble, save that the latter have a much smaller number of segments. The great number of segments in *Apus* and in some trilobites was a very annelidan character.

Dr. J. W. Gregory thought that all palæontologists would be glad that appendages in trilobites had been found and described by so careful a worker as Dr. Beecher. He thought that the new facts described confirmed the view of the close alliance of trilobites with the phyllopods for which Mr. Bernard had contended, but he still doubted whether its descent from an annelid was sufficiently proved. The limbs of *Apus* seemed to him more to resemble arthropod appendages than annelidan parapodia.

Mr. E. T. Newton also spoke.

The Author stated, in reply, that there seemed to be no escape from the conclusion that the immediate ancestors of *Apus* (and consequently of the trilobites) possessed between 60 and 70 segments; that is, they were annelids. Further, what we now know of *Apus* and of the trilobites enables us to trace step by step the course of the transformation of the chætopod into the crustacean.

It was not contended that *Apus* was an ancestral form of the trilobites, only that in its enormous number of trunk-segments, and in their cylindrical form, *Apus* had retained primitive annelidan characters which the trilobites had lost. On the other hand, as was shown in the paper, the trilobites (as represented by *Triarthrus*) had retained annelidan characters which had been lost in *Apus*. The position adopted by the Author in his previous paper was now fully confirmed,—the trilobites were to be regarded as fixed stages in the development of *Apus* from a chætopod, specialized for a creeping manner of life.

27. *An* Experiment *to* Illustrate *the* Mode *of* Flow *of a* Viscous Fluid.

By W. J. Sollas, M.A., D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Dublin. (Read April 24th, 1895.)

Now that the theory of glacier-movement propounded by James Forbes stands alone, undisturbed by conflicting hypotheses, we more readily perceive its simplicity and beauty; and we cannot refuse a tribute of admiration to the clarity of thought, no less to the skill in observation, which led that distinguished investigator to success in the treatment of a problem which his famous contemporaries had found so baffling.

Whatever may be the ultimate explanation, there can be no question of the fact, that the ice of glaciers behaves precisely like a plastic solid or highly viscous liquid; and it is consequently by enquiries into the laws of viscous flow that we may justly seek to extend our knowledge of the movements of flowing ice.

No substance is probably better suited for experiments in this direction than solid pitch, or that substance commonly known as 'cobbler's wax,' in which it occurs as the chief constituent. Under a sudden pull or pressure this material behaves like the most brittle solid, but when stress is slowly applied it yields continuously to deformation. A small fragment kneaded between the finger and thumb may be slowly drawn out into a thread of indefinite length, but if suddenly pulled it snaps across with a clean fracture; it may be readily impressed with the finger-nail, but a smart tap with the point of a needle shivers it into angular fragments.

While it thus essentially resembles ice in the manner in which it reacts against deforming forces, it possesses the advantage of being less viscous, and this, as well as a higher fusion-point, render it singularly well adapted for investigations in the laboratory.

The first to call attention to the similarity in the movement of flowing pitch and glacier-ice was Prof. Lewis Gordon (Phil. Mag. vol. xxvi. 1845, p. 206), and his observation, now fifty years old, is repeatedly cited by Forbes, always with approval; in one place indeed he speaks of it as 'a beautiful experiment,' though experiment it was not.

Since that time models of glaciers in pitch have frequently been made, and I myself, some fifteen years ago, had a model of the basin of the Mer de Glace carved in wood, and this, when supplied with pitch névé and glaciers, illustrated most of the phenomena of glacier-movement. But it is not merely for the purposes of class-room demonstrations that this substance may be employed; by its means we are enabled to study, at ease and with precision, the nature of those hidden movements which take place in the inaccessible interior of a glacier, or, more important still, of an ice-sheet.

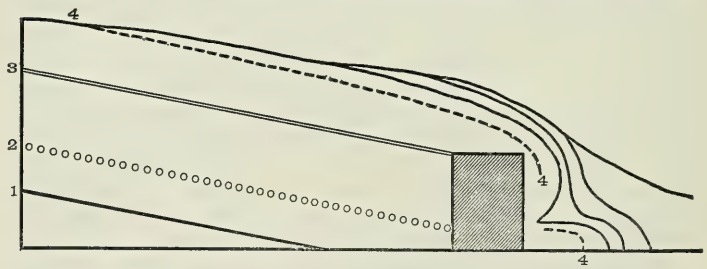
Of several experiments which I am now making I venture on this occasion to bring but one before the notice of the Society; the results obtained by it are so positive and striking that there can be no reason for delaying their publication.

A rectangular trough, measuring internally 6 cm. in width, 6 cm. in depth, and 30 cm. in length, was made of wood; it was closed at one end, and so constructed that by the removal of some screws it would readily fall into halves along a median longitudinal section. A barrier of wood 23 mm. in height and 20 mm. in breadth extended completely across the trough at a distance of 115 mm. from the closed end (fig. 3, p. 364).

The trough was placed in position for charging with cobbler's wax—perhaps for the sake of brevity we may be allowed to call this 'pitch'—by raising it at the open end, so as to give it a tilt of nearly 12°.

The pitch, melted by boiling it in a 'glue-pot' arrangement, was then poured in up to the level 1 (fig. 1); it was allowed time

Fig. 1.—*The pitch 'glacier' at the commencement of the experiment.*



1, 2, 3=layers within the pitch having an uniform slope of 11° or 12°.

4=original surface of the 'glacier.' The lines to the right of this represent the contours of succeeding surfaces in later stages of the experiment.

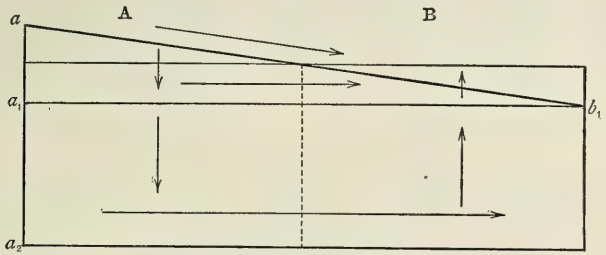
to solidify and then covered with an even layer of crystals of sugar, a substance which subsequent experience proved should be avoided in these experiments. Fresh material was poured in till the level 2 was reached, and on solidification an uniform layer of sago was spread over it. A third stratum of pitch was now added, and its surface thickly dusted with powdered vermilion; a last layer of pitch poured over this rose to the edge of the closed end of the trough on the one hand, and on the other just overbrimmed the summit of the transverse barrier. When the whole had cooled to the temperature of the room, the trough was untilted, and set to rest with its sole in a horizontal position. The upper surface of the wedge of pitch was consequently inclined at an angle of about 12°. Horizontal lines were now ruled across the upper surface of the 'glacier' at distances of 30, 60, 90, and 115 mm. from its highest

level at the closed end; the line 115 mm. distant lay immediately over the proximal face of the now buried barrier.

The object of the experiment will be seen from the following simple reasoning.

Since in fig. 2 the downward pressure due to gravity is greater

Fig. 2.



over that side of the mass of pitch which lies under A than over that under B, a movement and transfer of matter will take place from A towards B, till the two sides are in equilibrium. The transference might be partly accomplished by a superficial sliding down the slope AB, or as well by a general flow in the direction of the arrows.

But supposing the general flow to take place, one may ask whether it will be confined to the material which lies above the line a_1, b_1, or extend throughout the whole mass. This, indeed, is precisely the question to which the experiment was expected to find an answer.

One of the first phenomena observed was a marked sinking of the surface near the upper end of the 'glacier,' which made itself obvious simultaneously with the downward or forward curving of the transverse lines that had been ruled across the surface; a curvature, needless to add, due to the more rapid rate of flow near the centre of the trough. The sagging near the source was accompanied by a bulging immediately above the barrier, but this was less marked because the rising material to which it was due was comparatively rapidly carried away as it cascaded over the precipitous distal face of the barrier.

The movement of the transverse lines ruled on the surface was measured from time to time, and at irregular intervals, usually of a little over a week, fresh pitch was added to restore the original slope, which, owing to the continual sinking near the upper end, was diminished daily as much as one degree. A layer of powdered pigment was usually dusted on to the old surface before adding fresh pitch.

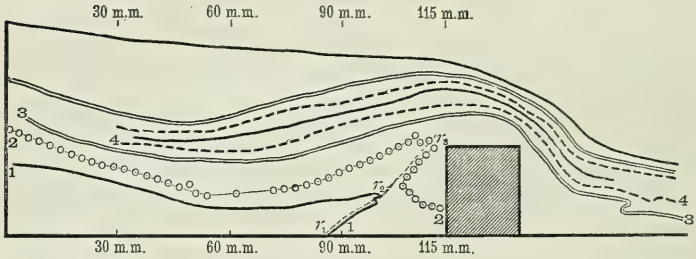
The experiment was started on December 27th, 1894, and brought to an end on March 24th, 1895, when the 'glacier' was split open longitudinally down the middle. During the eighty-seven days of its existence it had flowed at a fairly uniform rate, the average

velocity at the surface across the different sections being as follows:—

30 mm.	from the origin	.....	0·5 mm. per diem.
60	„	.....	1·0 „
90	„	.....	1·5 „
115	„	.....	2·0 „

It will be seen by reference to fig. 3, which represents at half the natural scale the longitudinal section through the middle of the 'glacier,' that the downward movement near the source, or in the region corresponding to the snowfield of a true glacier, has by no

Fig. 3.—*Longitudinal median section through the 'glacier' at the conclusion of the experiment.*



means been confined to the upper layers, but has affected almost the whole thickness of the pitch; a corresponding upward movement has taken place near the barrier, so that the layer numbered 3 has been lifted up and carried right over it, and layers 2 and 1 are following in its wake.

There is one particular in which pitch differs markedly from glacier-ice, and this is its powerful adhesion to the sides of the containing trough. The effect of this, however, is to produce a similarity in behaviour, since adhesion retards the movement of the bounding-surfaces of the pitch in the same manner as the friction of a rough and rugged channel retards the adjacent ice. The retardation owing to adhesion has amounted to actual arrest in the case of the lowest layers, where they touch the back of the trough, as is shown in fig. 4 (p. 365), which truly represents them as not having been there disturbed at all; a retardation has also naturally occurred at the sides of the trough, and the total result has been to give to all the layers the spoon-shaped form that has been so frequently commented on in the case of the successive layers of ice of a glacier. It is this adhesion which partly explains the loop-like form of the curves 1 and 2 in fig. 3, which represent in section the two lowest layers. Evidently there is less slipping between the pitch and its containing walls than between pitch and pitch.

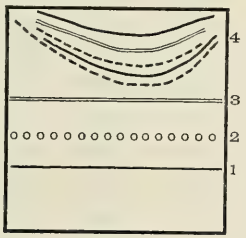
The extent to which the several layers have subsided in the region 30 mm. from the origin of the flow is given in millimetres in the following table:—

Layer.	I. Original Height.	II. Amount of Depression.	Ratio of I. to II.
1.....	13·5	4	10 : 3
2.....	21	8·5	10 : 4
3.....	41	22	10 : 5·37
4 (original surface) ...	54	33	10 : 6·1

The downward movement of the original surface of the 'glacier' at this section is thus seen to amount to almost four-fifths of the superficial movement down the slope, for the latter, as previously stated, was at this place 0·5 mm. per diem, or 43·5 mm. for the total of eighty-seven days that the experiment lasted. The underlying layers have evidently been less affected the greater their proximity to the bottom, but none have escaped disturbance altogether.

The total upward movement near the opposing edge of the barrier can only be determined in the case of the two lower layers, since the others were involved in the rapid flow due to the plunge of the material over the barrier. The dotted line $r_1 r_2 r_3$ in fig. 3 shows the direction along which the particles lying along it have travelled; in the case of layer no. 2 the movement along this line has carried a globule of sago, which was originally situated at r_2, upwards and forwards to r_3, a distance of 20 to 21 mm.; the vertical displacement is 16 mm., the horizontal 14 mm. Layer no. 1 has been similarly affected; the displacement from r_1 to r_2 amounts to 20 mm.; the horizontal and vertical components are nearly equal, and measure about 10 mm. each. It is interesting to compare these deep-seated movements with those of the surface over the same region, which is comprised between the lines 90 and 115 mm. from the origin; we have already seen that at 90 mm. the surface-flow was 1·5 mm., and at 115 mm. it was 2 mm. per diem, so that in

Fig. 4.—*The back of the 'glacier' at the conclusion of the experiment.*



Layers 1, 2, 3 are seen not to have suffered any displacement here, owing to the adhesion of the pitch to the back of the trough. Above 3 the pitch is fractured, so as to expose an obliquely transverse section of the original surface (4) and the succeeding layers. Subsidence is at a maximum near the middle, adhesion having prevented much movement near the sides.

the course of eighty-seven days the flow across the first line will have amounted to 130 mm. and across the second to 174 mm., whence it follows that the displacements below scarcely amount to more than one-tenth of those at the surface. This is no doubt to be partly accounted for by the steep slope down which the material flows on the far side of the barrier, but chiefly, I should imagine, to the resistance offered by the lower layers to shearing. Similar relations are probably to be found in nature, and one is reminded of the rapid movement of the ice on the western slopes of Greenland; the 16 to 60 feet a day which the glaciers accomplish there, as they descend from the interior, may not amount to more, or may be even less, than a tenth of this in the lower layers behind the 'nunataks.'

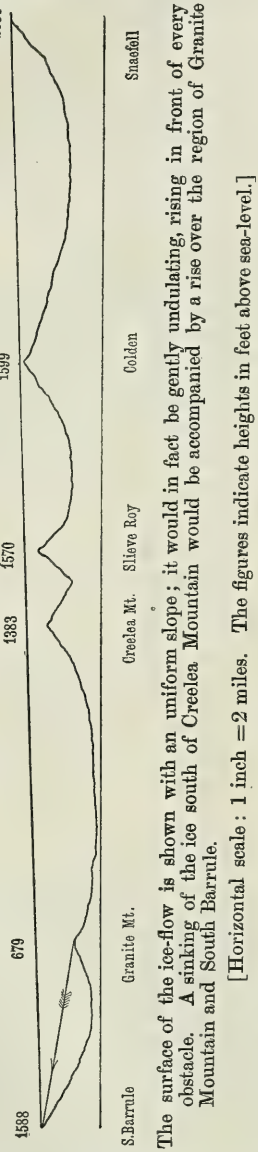


Fig. 5.—*Hypothetical section to explain the transport of boulders from Granite Mountain to near the summit of South Barrule.*

The surface of the ice-flow is shown with an uniform slope; it would in fact be gently undulating, rising in front of every obstacle. A sinking of the ice south of Creelea Mountain would be accompanied by a rise over the region of Granite Mountain and South Barrule.

[Horizontal scale: 1 inch = 2 miles. The figures indicate heights in feet above sea-level.]

It may be observed that nothing resembling ablation occurred in this experiment. I did not wish to complicate the problem by removing material; had I done so I must have taken more away from the lower than the upper regions of the 'glacier,' with the obvious effect of increasing the head of pressure under which the pitch moved, and so accelerating its movements both in a vertical and horizontal direction.

Probably one of the most surprising results obtained in the study of the distribution of glacial boulders is the discovery of travelled stones resting on mountain-sides at considerably higher levels than the parent rock from which they have been derived. Yet the fact is well established, and the evidence of the glacial striæ is in many cases in strict conformity with the evidence of the travelled stones.

Theoretical explanations founded on conjectures as to the manner in which ice-sheets might possibly rise in ascending currents have been met by theoretical objections; the experiment just described plainly shows, however, that under certain conditions such an ascending movement not only may, but undoubtedly must take place.

The slope of the upper surface of the pitch in my experiment is naturally much greater than will generally be presented by the surface of an ice-sheet, and the viscosity of ice is much greater than that of pitch; but these differences will not affect the final result. The viscous nature of glacier-ice once fairly admitted, it necessarily follows that, given time enough, this ice is bound to find its own level, in precisely the same sense that water is said to do so. Given sufficient time, and under the vertical pressure to which it is subject, an iceberg will (theoretically) flatten out into an infinitely thin film, and the reason that polar ice-sheets terminate in steep cliffs is that the ice breaks off faster than it flows out. There seems, then, no reason to doubt that a mass of ice occurring under conditions similar to those of our experiment would move in the same way; and without necessarily committing myself to the hypothesis that stones have actually been carried upwards from their source by ascending currents of ice, I am compelled to admit that, given the necessary conditions, its possibility cannot be denied. If we turn to the observations in the Isle of Man, first made by Mr. Cumming, and lately confirmed and extended by Mr. P. F. Kendall, we find that fragments have been carried from Granite Mountain (fig. 5, p. 366), which does not attain a greater height than 679 feet, on to the flanks of South Barrule, up to 100 feet below its summit, which is 1588 feet above the sea-level. Now if the Isle of Man were, as extreme glacialists suppose, hemmed around by confluent glaciers of considerable thickness, not necessarily overwhelming Snaefell, it would appear well within the range of possibility that the snowfall on Snaefell and the mountains to the south and west of it may have produced an ice-flow with an upper surface somewhat as in the diagram on the opposite page. Between South Barrule and Creelea Mountain there would have been situated a great lake of ice under a higher pressure at its northern than its southern end, and the natural result would have been an ascending forward movement on the south: this we may suppose, without being guilty of an absurdity, capable of transporting boulders from Granite Mountain into the position that they now occupy on South Barrule.

Those who treat the absence of evidence as evidence of absence have asserted that by no possible process can stones be introduced from the floor of a glacier into its substance, and it is possible that they might until quite recently have objected that, while ice might ascend South Barrule, it could not pick up fragments from Granite Mountain; fortunately we are now in possession of Mr. Chamberlin's observations on the glaciers of Greenland,[1] which not

[1] Bull. Geol. Soc. America, vol. vi. (1895) pp. 199-220.

only show that the lower layers of the ice are densely charged with detritus, but explain the manner in which it is introduced from the bottom.

Again returning to the experiment, it will be observed that the elevation of the third layer as it surmounts the barrier is so great that it is carried completely clear of it; and if such a disposition of ice and barrier should occur in nature, it would be possible to find boulders, on the far side of a mountain, which had been brought from hills lower than itself, situated on its near side; while on the barrier and in the intervening regions such boulders might prove, to the embarrassment of the observer, to be wholly absent. Whether such an extreme case has been recorded I do not know, but instances of boulders which have been carried right over mountain-summits are not infrequent.

A much controverted question has been the mode of flow of glaciers over deep lake-basins, and the suggestion has been made that the sheet of ice above the general level of the brim of a lake-basin would shear away from that below, which would remain quietly at rest like a stagnant pool. Such a conception is distinctly inconsistent with the results of this experiment, which show that the ice would certainly be in motion throughout its mass. How far the ice might actually be capable of eroding a lake-basin is a question which experiments in progress may assist in solving.

Discussion.

Mr. W. W. Watts, referring to two scratched stones exhibited by him, stated that they had been picked up on a moraine which came up through the ice at the lower part of the Findelen Glacier, near Zermatt. Although the stones were clearly found at a lower level than their point of origin, and although it was quite possible that the moraine made its appearance at a lower level than the point at which the stones had touched the bed of the glacier, it was quite clear that they had been at the bottom of the glacier, and had made their way up through the ice in the same way as the grains of sago in Prof. Sollas's experiment.

Sir Henry Howorth also spoke.

28. *On* Fluvio-Glacial *and* Interglacial Deposits *in* Switzerland. By C. S. Du Riche Preller, M.A., Ph.D., F.G.S., A.M.I.C.E., M.I.Elect.E., F.C.S. (Read March 20th, 1895.)

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I. Introduction.

In a paper published in the Geological Magazine for January 1894, I showed that the Swiss Alps had been visited not only by two, but by three general glaciations, of which the first may be referred to Pliocene, the second to Middle Pleistocene, and the third to Upper

Fig. 1.

Pleistocene times. The evidence consists chiefly in a number of glacial and so-called fluvio-glacial deposits which I had examined in the Swiss lowlands, and notably in the vicinity of the Lake of

Zürich, where, perhaps more than in any other part of Switzerland, such deposits are laid open within a comparatively small and easily accessible area.

Fig. 2.

The first suggestion of certain gravel-beds at the foot of the Italian Alps being older than the two Pleistocene glaciations then generally accepted may be said to have emanated from Stoppani,[1] Desor,[2] and notably from Renevier,[3] as early as 1875. In 1882, Prof. Penck[4] succeeded in showing, on the evidence of Decken-

[1] 'Il Mare Glaciale ai piedi delle Alpi.'
[2] 'Paysage Morainique.'
[3] 'Relations du Pliocène et du Glaciaire aux Environs de Côme,' Bull. Soc. géol. France, ser. 3, vol. iv. (1876) p. 187.
[4] 'Die Vergletscherung der Deutschen Alpen,' Leipzig, 1882.

schotter or plateau-gravel, that the Bavarian and Austrian Alps had been visited by three different glaciations; but as regards the Swiss Alps, even such distinguished glacial geologists as Prof. Heim hesitated to adopt that view, until quite recently, namely in 1891, Dr. Léon Du Pasquier, of Neuchâtel, showed in a valuable memoir[1] that the fluvio-glacial gravels deposited in the valleys of the principal river-systems in the North of Switzerland admit of being classed in three distinct categories, to wit, Cavernous Nagelfluh (the Swiss equivalent for Deckenschotter), Upper Terrace-, and Lower Terrace-gravels. Dr. Du Pasquier's conclusions, resting as they do on fluvio-glacial evidence, are fully borne out by the morainic deposits in the Zürich district (described in the Geol. Mag. paper already quoted); and I now propose to submit some further evidence of so-called 'fluvio-glacial' and 'interglacial' deposits which I examined during the summers of 1893 and 1894, in the vicinity of the Lakes of Zürich, Constance, Zug, and Thun, and with reference to some of which my conclusions differ in several important respects from those recently arrived at by Swiss geologists.

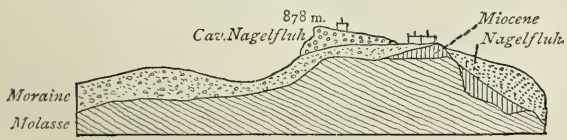
As regards definitions, I may say that the term 'fluvio-glacial' refers to deposits which have been formed by rapidly-flowing glacier-streams at or some distance from terminal moraines; while the term 'interglacial' does not, of course, imply that during such a period the Alps were free from ice, but refers to deposits formed during more or less protracted periods intervening between general glaciations: that is, to periods during which the glaciers were restricted to the Upper Alpine regions, where they oscillated within comparatively narrow limits, as they do in our own day. Hence both fluvio-glacial and interglacial gravel-deposits are essentially fluviatile in character, as distinguished from morainic or glacial deposits properly so-called.

II. Deposits near the Lakes of Zürich and Constance.

1. *Cavernous Nagelfluh.* (Figs. 1 to 5.) The remarkable fluvio-glacial deposits of Pliocene, so-called 'löcherige' or Cavernous Nagelfluh, on the summit of the Uetliberg near Zürich (fig. 3), and

Fig. 3.

Uetliberg, n. Zürich.



near Baden, about 15 miles below Zürich (4, fig. 1, p. 369), were described in the paper already quoted (Geol. Mag. 1894).

[1] 'Fluvio-glaciale Ablagerungen in der Nord-Schweiz,' Beiträge zur geol. Karte d. Schweiz, 1891.

Since then I have examined several other deposits, notably that on the summit of the Gebensdorfer Horn (5, fig. 1, p. 369), about 4 miles west of Baden, near Turgi, the point of confluence of the rivers Aare, Reuss, and Limmat; and an extensive bank about 2 miles in length in the Glatt Valley east of Zürich, between Uster and Wetzikon (6, fig. 1). All these deposits are characterized by practically the same features and composition: that is, they show occasional stratification; the pebbles in the upper portions are, on the whole, better rounded than in the lower portions, where they are often striated; and the deposits generally pass into sand, and, in some cases, into moraine. The Uetliberg, and in part also the Baden deposit, rest on moraine, while the Gebensdorf and Glatt Valley deposits rest directly on Molasse, the last-named being overlain by moraine. The Uetliberg deposit was formerly regarded as diluvial but pre-Glacial, as distinguished from the well-known Miocene Nagelfluh of the Molasse formation; and even after it had been established that it rested on moraine, it was considered a purely local deposit formed by a temporary stream wedged in between two glaciers. But the three other deposits west and north of the Uetliberg to which I have referred, as well as similar deposits in other parts of Northern Switzerland, lead to the conclusion that they are part of the same complex of plateau-gravel, more or less coinciding with the terminal moraine of the first glaciation. All the deposits I have mentioned are from 100 to 200 feet in depth, and have the same characteristic cliff-like appearance. The longitudinal section (fig. 4, p. 373) of the Uetliberg, Baden, and Gebensdorf deposits shows that they all lie in the same line, the fall being about 1000 feet in 20 miles or 1 in 100. In the transverse section (fig. 5), from the Uetliberg range to the Glatt Valley, in which are also marked the glacial deposits of the three successive glaciations, the Uetliberg and Glatt Valley Nagelfluh appears not only at both extremities, but also in the Zürich lake-valley, fully 1000 feet below the summit of the Uetliberg, a fact which attests the great depth of the original complex, and the powerful erosive action which followed its deposition.[1] As is known, the qualification 'löcherige' or 'cavernous' refers to the hollows formed by the limestone-pebbles leached out by percolating water, the carbonate of lime being precipitated and constituting a cement composed of layers of calcareous film.

2. *Lignite-deposits.* (Figs. 1 and 6.) The interglacial lignite-deposits of Dürnten, Wetzikon, and Uznach, near the upper end of the Lake of Zürich, and those of Moerschwil, between the town of St. Gall and the Lake of Constance, were first mentioned, as is well known, by Oswald Heer, as early as 1865,[2] and even in the most recent text-books his description is still reproduced. But these

[1] [The same phenomenon is observable at Baden, where I have (since this paper was read) found a cliff ½ mile in length and 50 feet in depth, bordering the left bank of the river Limmat, at 364 metres above sea-level, or about 400 feet lower than the Devil's Cave deposit.—May, 1895.]

[2] 'Urwelt der Schweiz,' Zürich, 1865.

Fig. 4.

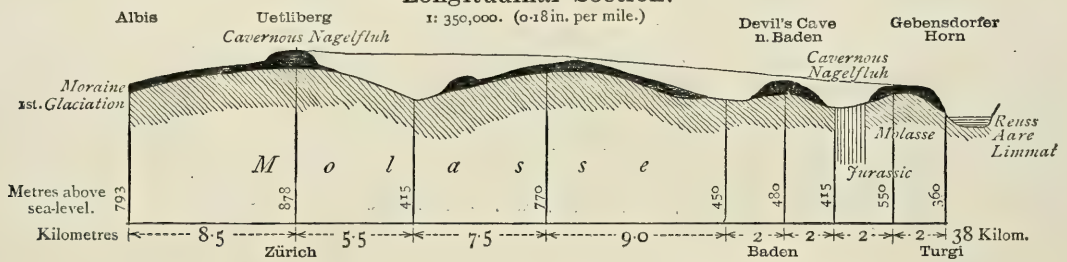
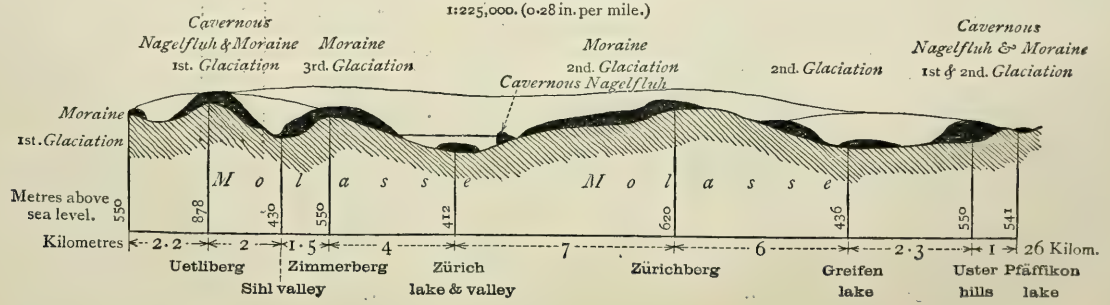


Fig. 5.



Du Riche Preller del.

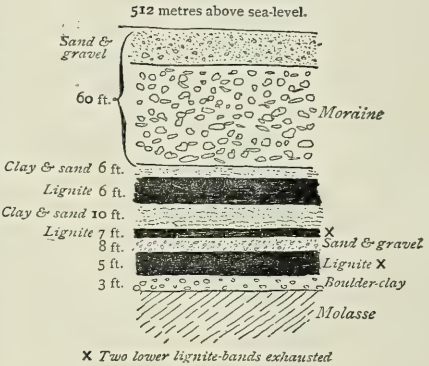
deposits now present conditions differing widely from those existing in Heer's time. The deposits of Dürnten and Wetzikon were exhausted many years ago, the workings being obliterated, and the pits filled with water. On the other hand, the deposits of Uznach (7, fig. 1, p. 369), and those of Moerschwil near St. Gall, are, to a small extent, still worked, the succession of strata of the Uznach deposit being shown in fig. 6, below. Here only the uppermost seam, about $5\frac{1}{2}$ feet in thickness, is now worked, while at Moerschwil the lignite-band does not now exceed 3 feet in depth, the strata being as follows:—

564 metres above sea-level.	Sand and gravel	10 feet
	Moraine	20 „
	Lignite	3 „
	Clay	3 „
	Sand and gravel.	

The sand and moraine overlying the uppermost Uznach lignite-deposit contain polished and striated boulders largely derived from the Glarner Alps or Linth watershed, notably red sandstone or Sernifite and green Tavayanaz sandstone, whilst the boulders of the underlying clay are in part derived from the Grison Alps or Rhine watershed, such as Puntaiglas granite and diorite. This fact affords proof that the Uznach and Dürnten lignite-deposits were formed after the second glaciation, when a connexion existed between the Rhine and Linth river-systems, and part of the Rhine glacier reinforced that of the Linth, as was pointed out in the Geol. Mag. paper already quoted. According to Heer, the Uznach, Dürnten, and Wetzikon deposits were parts of a former continuous lignite-bed, probably formed in an extensive lake. There is, however, no trace of continuity; moreover, the distance of about 20 miles between the two deposits and the difference of level (over 100 feet) between them militate against Heer's assumption. There can be no doubt that these deposits, as also those near the Lake of Constance, were simply local and isolated peat-mosses formed on boulder-clay,[1]

Fig. 6.

Uznach, n. Lake Zürich



[1] The term 'boulder-clay' denotes throughout this paper the comparatively thin layer of clay which, in the Swiss Alps, generally forms the lowest parts of glacial deposits. It is essentially a product of abrasion, and corresponds to the 'Geschiebe-Lehm' of Swiss geologists, this term being, in fact, simply a trans-

in stagnant pools and under climatic conditions very like those of our own day. Such peat-mosses of post-Glacial age exist in abundance in the same locality, and always afford evidence of underlying boulder-clay, whose impermeable nature is eminently favourable to their formation.

As is well known, peat is composed chiefly of the dead parts of weeds and moss, whose capillary structure promotes their growth by the constant absorption of water from below. The pressure of sand, gravel, and moraine subsequently deposited on the Pleistocene Uznach, Dürnten, and Moerschwil peat-mosses, and the stoppage of their further growth by the exclusion of feed-water, converted them gradually into more or less slaty lignite. The quality of the lignite improves with the depth—that is, with the pressure to which the lignite is subjected, as is evidenced by the three superposed Uznach seams, of which the lowest was of a much better quality than the now remaining uppermost band.

According to Heer, the formation of the Dürnten lignite-deposit, about 20 acres in superficial area and 3·75 feet in depth, required 2400 years,[1] which he considered a fair estimate of the duration of that interglacial period. But the three superposed Uznach lignite-seams, which are together 10 feet in depth, must, on the same computation, have taken 6600 years to form, irrespective of their considerably larger area, and of the time required for the deposition of the fluviatile sand and gravel by which they are covered. This shows that Heer's figure, although it is still regarded as an axiom by many geologists, can, at the most, apply only to an isolated local instance, and therefore possesses no general value as to the duration of the second interglacial period.

III. Deposits near the Lake of Zug.

Lorze Valley Nagelfluh. (Figs. 1, 2, and 7.) One of the most extensive fluvio-glacial deposits in Switzerland is that exposed in the Lorze Valley above Baar, about 4 miles from the town and Lake of Zug (8, fig. 2, p. 370). The successive layers following upon the Miocene Molasse are:—(1) about 30 feet of old moraine; (2) about 400 feet of fluviatile conglomerate, occasionally stratified and intermingled with dykes and layers of sand in places hardened to sandstone; and (3) about 130 feet of younger moraine. Longitudinally, the deposit forms the so-called Menzingen plateau and covers a superficial area 3 miles in width and 4 miles in length, the surface being characterized by numerous hollows and depressions which

lation of 'boulder-clay.' It is frequently confounded with the term 'ground-moraine,' as distinguished from surface-moraine. But of ground-moraine—that is, of morainic deposit below glaciers—there is very little in Switzerland, the bulk of the glacial deposits being composed of surface-moraine; that is, of material which glaciers carry on their backs and which falls to the ground when the glaciers melt.

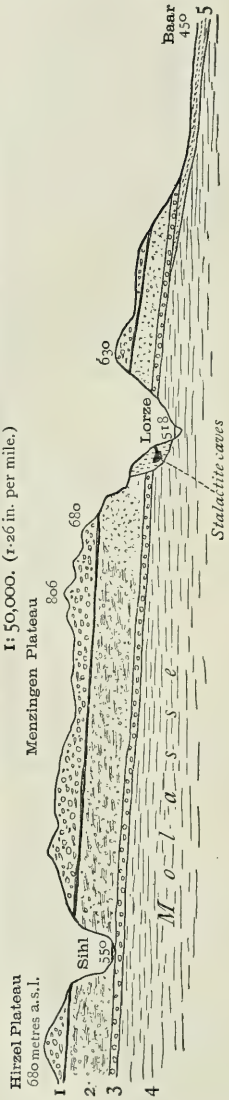
[1] Heer's computation may be shortly expressed as follows:—One acre of peaty soil absorbs 15 cwt. of carbon per annum. One acre of lignite 3·75 feet in depth contains 36,000 cwt. of carbon; hence $\frac{36,000}{15} = 2400$ years.

offer no outlet to rain-water, so that the latter percolates through the upper moraine and the conglomerate, and collects in copious springs on the Molasse, where it has, from the same cause, also formed the extensive stalactite-caves of the Lorze ravine. As shown in the accompanying section (fig. 7), this deposit is intersected in two places: (1) by the river Sihl, which rises in the Schwyz Alps about 12 miles beyond the Convent of Einsiedeln, and now discharges into the river Limmat immediately below the lake and town of Zürich; and (2) by the Lorze torrent, which drains the mountain-lake of Aegeri and discharges into the Lake of Zug and, after leaving the latter, into the Reuss. The imposing gravel-deposit through which the Lorze has thus cut its bed down to the Molasse marks the ancient deflected course of the Sihl. This river was originally the main feeder and pre-Glacial erosive agent of the Zürich lake-valley, into which it discharged practically as a waterfall near the upper end of the present lake.[1] The first advance of the Linth glacier deflected the Sihl and its glacier to the left—that is, to the Reuss basin. During the second glaciation, its new course was in its turn banked up by the Reuss glacier, and it again found its way into the Zürich basin, though at a somewhat lower point than before—that is, at the present island of Au (11, fig. 2, p. 370), as evidenced by an extensive deposit of gravel-conglomerate younger than the Pliocene Nagelfluh of the Uetliberg. The third advance of the Linth glacier again forced the Sihl to the left; but the old outlet to the Reuss basin being banked up, it was com-

Fig. 7.

Longitudinal Section, Old Sihl Deposit, Lorze Valley, n. Lake Zug.

1:50,000. (1·26 in. per mile.)



[1] The old point of outflow near Schindellegi is clearly indicated by the topographical features of the locality. The altitude of the Sihl at Schindellegi is about 800 metres, that of the lake 409 metres above sea-level; but the horizontal distance is only 3 kilometres; hence the fall must have been about 400 metres, or at the rate of 1 in 8.

pelled to scoop out its present bed, which lies closely parallel to, but outside, the drainage-area of the Lake of Zürich, as shown in the map, fig. 2, p. 370.

In his memoir already quoted, Dr. Du Pasquier refers incidentally to the Lorze Valley Nagelfluh and regards it as contemporaneous with the Uznach and Dürnten lignite-deposits, that is, as belonging to the second interglacial period. But two facts militate against this conclusion: first, that the Pliocene 'Cavernous Nagelfluh' of the Uetliberg near Zürich is indisputably derived from the Linth basin or Glarner Alps, as evidenced by the predominance of red Sernifite-pebbles, so that at that time the Sihl must have been already deflected to the Reuss basin, where it formed the deposit under notice; and secondly, that the Sihl Nagelfluh of the Lorze Valley exhibits all the characteristics of the Uetliberg Nagelfluh save, of course, in the composition of the pebbles. These in the Sihl deposit are derived chiefly from the Neocomian and Flysch limestone and sandstone strata of the upper course of that river. The Lorze Valley-deposit must therefore be regarded as the indirect product of the first and not the second glaciation, and the same applies to the smaller outlying deposits of Blickendorf and Sihlbrugg, near Baar (9 and 10, fig. 2, p. 370), which probably mark an old serpentine course of the river Sihl, and are at any rate part of the same original complex.[1]

As regards the underlying moraine, Prof. Heim refers it, as well as the overlying moraine, to the Reuss glaciers.[2] No doubt the ancient course of the Reuss was not through the lower part of the Lake of Lucerne, but from Brunnen through the Goldau Valley and through the present Lake of Zug (figs. 1 and 2, pp. 369, 370); but, so far as my examination on the spot goes, the gneiss and granite-boulders characteristic of the Reuss drainage-area are absent in the morainic deposits of the Lorze Valley properly so-called. Hence these deposits must be referred to the old Sihl glacier, and in part to the Aegeri glacier.

In connexion with the Lorze Valley-deposit, it may be mentioned that the indiscriminate use of the terms 'delta' and 'débris-cone,' as applied to this and similar gravel-beds, is a fruitful source of confusion. Prof. Heim and others speak of the Lorze Valley-deposit as an old delta, whilst Dr. Du Pasquier terms it a 'schuttkegel' or débris-cone. As the last-named writer justly points out, deltas are subaqueous deposits formed by rivers discharging into still or sluggish water such as the main affluents of lakes or of the sea, or into flowing water, such as the tributaries of large rivers; whereas débris-cones are accumulations formed on *terra firma* by lateral torrents. The Sihl, being at the time an affluent of the Reuss, must have formed in the first instance an extensive delta which

[1] [Since this paper was read, Dr. Aeppli, of Zürich, has referred to the Lorze Valley, Blickendorf, and Sihlbrugg deposits in a monograph on 'Die Entstehung des Zürichsees' (Beiträge zur geol. Karte d. Schweiz, 1895). His conclusions as regards the Lorze Valley-deposit substantially agree with mine, while he refers the smaller outlying deposits to a younger glaciation, a conjecture of which the accuracy may, however, fairly be doubted.—May, 1895.]

[2] Neujahrschrift der Naturf. Gesellschaft Zürich, 1891.

probably reached to the banks of the present Lake of Zug; while the gravel-deposits in the Lorze Valley and its neighbourhood are the results of banking up by the main glacier of the Reuss, which, flowing more or less at right angles, constituted a formidable barrier. Hence the Lorze Valley-deposit, formed outside the main river, is essentially a débris-cone superposed on the old delta.

IV. Deposits near the Lake of Thun.

Hardly less remarkable than the deposits near the Lake of Zug are those in the Kander Valley near the lower end of the Lake of Thun. This last-named interesting, but complex district has been dealt with by various Swiss geologists, notably by Studer as early as 1825, 1834, and in 1871,[1] by Bachmann in 1870 and 1876,[2] and quite recently (namely in 1892) in a very able memoir by Dr. Zollinger of Bâle.[3] As is seen from the plan of the district (figs. 8 and 9, pp. 379, 380), the rivers Kander and Simme, both of which rise in the Bernese Oberland and have a combined drainage-area and volume about equal to those of the Aare at the upper end of the Lake of Thun, have their confluence about 2 miles from the present lake, and discharge into the latter, about midway between Thun and Spiez. Up to the year 1714 the Kander, reinforced by the Simme, flowed from Glutsch to the left, through the present Glutsch Valley, and discharged, not into the lake, but into the river Aare just below Thun. The large volume and deposit carried by the Kander naturally banked up the river Aare, and with the view of removing the danger of frequent inundations, the Kander was, in 1714, artificially deflected from the Glutsch Valley into the lake by a tunnel near Strättlingen cut through the intervening gravel and moraine-ridge.[4] The considerably increased fall (1 in 20) and shorter flow of the new outlet naturally caused not only the rapid formation of a delta at the outflow into the lake, but the gradual falling-in of the tunnel, and the deepening of the river-bed. This latter is now 150 feet below the original artificial level of 1714, although the process of backward erosion has gradually equalized the variations of fall between the confluence and the lake as well as the rate of deposition at the delta.[5]

[1] 'Beyträge zu einer Monographie der Molasse,' Berne, 1825; 'Geologie d. westl. Schweizer Alpen,' Heidelberg & Leipzig, 1834; 'Zur Geologie des Ralliger Gebirges,' 1871.

[2] 'Kander,' 1870; 'Geologisches über die Umgebung von Thun,' Jahrb. Schweiz. Alpenclub, vol. xi. (1876) p. 371.

[3] 'Zwei Flussverschiebungen Bern. Oberland,' 1892.

[4] The river Lütschinen, which formed the delta of Interlaken, now separating the lakes of Brienz and Thun, was similarly diverted into the former lake as early as 1257. Another artificial deflection was that of the Linth into the Lake of Wallen, in 1815.

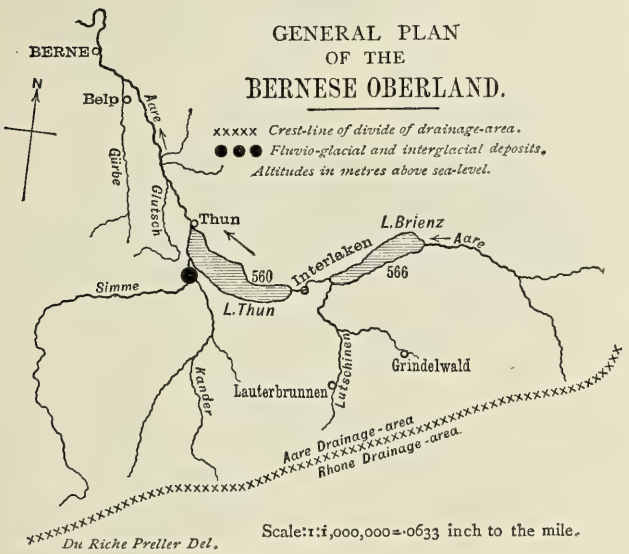
[5] From the official measurements quoted by Dr. Zollinger, the rate of formation of this delta from 1714 to 1857, namely, in 143 years, is as follows:—

1714 to 1716 =	3 years;	20 hectares	= 50 acres	= 16·66 acres per annum.			
1716 „ 1740 =	24 „ ;	30 „	= 75 „	= 3·12 „	„	„	
1740 „ 1777 =	37 „ ;	8 „	= 20 „	= 0·44 acre	„	„	
1777 „ 1857 =	80 „ ;	7 „	= 17·5 „	= 0·22 „	„	„	

Total 65 hectares = 162·5 acres in 143 years = mean 1·14 acre per annum.

But beyond and parallel to the old Kander Valley, which is now traversed only by a small artificially-deflected stream, viz. the Glutsch, there runs, in a north-westerly direction from the confluence of the Kander and Simme, another, considerably broader, namely the Stocken Valley, which is separated from the present Glutsch Valley by a Triassic ridge and joins the Aare Valley at Belp, about 12 miles below Thun (fig. 8). This Stocken Valley probably

Fig. 8.



marks the original, pre-Glacial outlet of the Kander and Simme which was afterwards barred by a débris-cone; there is, moreover, evidence that at a subsequent period the two rivers discharged separately into the lake, the Simme to the N.W. of Spiez, and the Kander to the S.E. of Spiez, near the village of Faulensee. The various deflections of the river-courses are shown in the plan, fig. 9, p. 380.

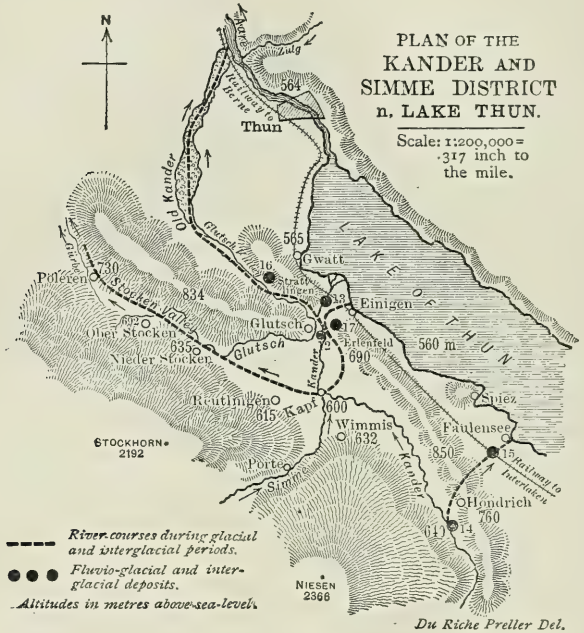
As regards the abundant, and in places well exposed, fluvio-glacial and interglacial deposits in the district, it will be convenient to point out that the boulders and pebbles derived from the Aare, Kander, and Simme drainage-areas are in the main as follows: for the Aare, dark slaty gneiss, chloritic gneiss, pale protogine or Grimsel granite and verrucano, in places also red marble and black limestone of the Lauterbrunnen Valley; for the Kander, Eocene slates and limestone, Gasteren granite, mica-gneiss and Tavayanaz sandstone; for the Simme, Eocene so-called 'hornfluh,' Cretaceous, Neocomian, and Jurassic, and notably red dolomitic limestone, and red and greenish hornstone; and for the present joint course of the Kander and Simme, rauchwacke and gypsum, of which latter a band

crosses the Kander at Erlenfeld near Glutsch, about midway between the confluence and the lake.

Among the more typical deposits examined are the following:—

1. *Simme Deposits.* Below the confluence of the Kander and Simme, in the ravine near the point where the Glutsch stream

Fig. 9.



discharges its overflow water into the joint river (12, fig. 9), the following section is exposed:—

Left bank.	Gravel-conglomerate	25 feet.
	Moraine and sand	15 „
	Blue and yellow boulder-clay.	10 „
	Triassic limestone.	

Both the boulder-clay and the superposed moraine contain boulders of the Aare area. On the other hand, the gravel-conglomerate or Nagelfluh is, from the character of the pebbles, evidently derived mainly from the Simme and not from the Kander, seeing that the red limestone and hornstone of the former predominate, while the Gasteren granite and Tavayanaz sandstone of the latter are absent. Somewhat lower down, in the eroded gully formed by the broken-in tunnel (13, fig. 9), the same Nagelfluh re-appears in the following characteristic section, which is the complement of the first:—

Right bank.	Moraine	120 feet.
	Gravel-conglomerate	150 „

The gneiss and Grimsel granite-boulders both in the upper moraine and in the underlying boulder-clay characterize them both as derived from the Aare area. This combined section, therefore, affords evidence that after the first glaciation the Simme flowed separately into the lake-basin, and formed on the old Aare moraine a delta upon which was superposed a débris-cone when the second advance of the Aare glacier barred its outflow.

2. *Kander Deposits.* Below the village of Hondrich, in a double curve described by the Kander (14, fig. 9), there is the following exposure :—

Right bank.	Moraine	30 feet.
	Gravel-conglomerate	60 „
	Moraine.	

The gneiss and granite-boulders in both the overlying and the underlying moraine prove the latter to have been derived from the Aare area, while the cemented conglomerate (in which pebbles of Gasteren granite and Tavayanaz sandstone predominate) was deposited by the Kander. The same conglomerate re-appears between the first section and the lake, in a cutting of the recently opened railway from Thun to Interlaken (15, fig. 9), the exposure being as follows :—

Moraine	30 feet.
Gravel-conglomerate	10 „
Moraine.	

In this section, too, the boulders of the upper and lower moraines are derived from the Aare area, and the pebbles of the coarse conglomerate from the Kander. The two deposits taken together, therefore, show that, after the first glaciation, the Kander flowed separately into the lake and formed the delta of Faulensee on the old Aare moraine.

3. *Kander and Simme Joint Deposits.* The second advance of the Aare glacier having barred the separate courses of the Kander and Simme by a moraine-ridge even now more than 350 feet above their present level, they were deflected to the north-west into the present Glutsch Valley. Of this, conclusive evidence is afforded by an interesting exposure in a spur of the almost perpendicular cliff on the right-hand side of the valley, about 1½ mile from the village of Glutsch (16, fig. 9). This section was mentioned by Studer in his 'Monograph on Molasse' as early as 1825, as containing a band of lignite, which is, however, so thin that it can be detected only after very careful search. The exposure is as follows :—

Moraine	12 feet
Gravel	30 „
Lignite	0·5 „
Moraine Boulder-clay	2 „
Gravel-conglomerate	20 „

The complement of this section is found opposite Glutsch, on the right bank of the Kander, near Erlenfeld (17, fig. 9), and is composed as follows:—

Gravel-conglomerate.....	10 feet.
Moraine	10 „
Boulder-clay	2 „
Rauchwacke and gypsum.	

The lowest boulder-clay and moraine contain, besides gneiss and protogine or granite-blocks from the Aare area, a few re-transported boulders of Gasteren granite and mica-gneiss of the Kander area, while the coarse conglomerate in both sections only contains pebbles derived from the Aare, and the same applies to the boulders of the second moraine. The slaty lignite-band is simply compressed peat, and precisely similar to the lignite-seams near Uznach and St. Gall already described. In the upper gravel and third moraine the pebbles and boulders are entirely composed of the various limestones and sandstones of the Kander and Simme valleys, as well as of the Gasteren granite and Tavayanaz sandstone of the Upper Kander. By combining the two sections, we have therefore three distinct alternations of moraine-deposit, and hence clear evidence of three successive glaciations.

Dr. Zollinger avers that the coarse gravel-conglomerates of the two last-named sections are fluvio-glacial products of the second glaciation, whilst the conglomerates of Hondrich and in the railway-cutting, as well as those in the ravine near Glutsch, and of the old Kander tunnel, are in his opinion contemporaneous with the lignite-band—that is, belong to the second interglacial period.

But these conclusions appear untenable for the following reasons:—

(1). Because the upper gravel of the joint Kander and Simme, underlying the third or uppermost moraine, and deposited during the same interglacial period as the lignite-band, is indisputably much younger than the various conglomerates deposited, as has been shown, by the two rivers during their earlier, separate flow into the lake area.

(2). Because the difference between these conglomerates and the coarse conglomerate of the Aare, underlying the second moraine in the Glutsch Valley, is only one of petrological composition of the pebbles, while in all other respects they all constitute a genuine Nagelfluh and, as such, must be regarded as of the same age as the Nagelfluh of the Uetliberg and the Lorze Valley.

These conclusions are, moreover, confirmed by Bachmann, who considered the conglomerates of the Kander district as much older than the deposits of the two Pleistocene glaciations which were then held to constitute the Ice Age in the Alps.

V. Conclusions.

The age of the younger interglacial lignite- and gravel-deposits of Uznach, Moerschwil, and of the Kander Valley admits of being determined not only from stratigraphical and petrological, but also from palæontological evidence, such as the remains of *Elephas antiquus* and others found by Heer in the Dürnten and Wetzikon lignites. But in the older fluvio-glacial and interglacial gravel-deposits described in this paper—namely, those of the Uetliberg, Baden, Gebensdorfer Horn, and Glutsch Valley, of the Lorze Valley near Zug, and of the Kander Valley near Thun—no fossils have so far been found, and their age can be fixed only by their stratigraphical position and petrological character, in conjunction with analogous deposits in other parts. As regards the latter, the only fossil so far met with in the plateau-gravel or Deckenschotter appears to be *Helix hispida*, found by Dr. Schill[1] in the Cavernous Nagelfluh of the Ueberlingen district (Grand Duchy of Baden), bordering on the Lake of Constance. The only fossil so far found in the Deckenschotter of the Bavarian and Austrian Alps appears to be a *Helix* which Prof. Penck claims to have discovered in the Traun-Ems district (Salzkammergut)[2]; but the Upper Pliocene plateau-gravel of the Bresse district near Lyons, called by French geologists 'Alluvions anciennes des plateaux,' as distinguished from the younger 'Alluvions des terrasses et des vallées,' contains, according to Fontannes,[3] *Elephas meridionalis* and *Mastodon arvernensis*; and fossils of the latter occur, according to Delafond,[4] also in the Rhone Valley above Lyons—that is, in the sand- and gravel-deposits which constitute the uppermost of the three gravel-terraces—and are found in depressions of the Pliocene marl. As another analogous formation may be regarded the Upper Pliocene 'alluvioni antichi' of Upper Italy, which, as already mentioned, Italian geologists have long considered pre-Glacial in respect of the then accepted two Pleistocene glaciations.[5] In Switzerland itself, the old deltas and débris-cones of the Muotta at Iberg, near Brunnen, on the Lake of Lucerne; of the Engelberg Aa, near Buochs, on the same lake; in Savoy the Drance delta described by Morlot,[6] and other similar deposits, as well as the loess along the base of the Jura, further swell the number of fluvio-glacial and interglacial deposits, though the exact age of their deposition has yet to be determined.

[1] 'Beschr. d. Umgegend von Ueberlingen', 1859.
[2] 'Oesterr. Alpen-Vorland,' 1890.
[3] Bull. Soc. géol. France, ser. 3, vol. xiii. (1884) p. 59.
[4] *Ibid.* vol. xv. (1886) p. 65.
[5] The Norwich Crag and Forest Bed formations may be regarded as probably contemporaneous with the Pliocene or first glaciation and the Lower Pleistocene or first interglacial period, showing that that part of Britain was not glaciated in Pliocene times.
[6] Bull. Soc. Vaud. vol. iv. 1854.

As regards the deposits more especially dealt with in this paper, they may be tabulated as follows[1]:—

Geological Periods.	Glacial and Interglacial Periods.	Fluvio-Glacial and Interglacial Deposits.			Analogous Deposits.
Present.	Post-glacial.				
Upper Pleistocene.	Third glaciation.				
Middle Pleistocene.	Second interglacial period.	Interglacial deposits.	Lignite-bands.	Upper Gravels of Kander. Uznach. Moerschwil. Kander.	Lignite-deposits, Sonthofen, Algau, Bavaria; Chambéry, Savoy; Leffe, North Italy. Alluvions des terrasses, Rhone Valley, and Bresse district, Lyons.
	Second maximum glaciation.	Fluvio-glacial deposits.		Upper Terrace-gravels.	Upper Terrace-gravels, North Switzerland.
Lower Pleistocene.	First interglacial period.	Interglacial deposits.	Gravel-conglomerates or Cavernous Nagelfluh.	Kander and Simme / Thun. Lorze Valley / Zug. Glatt Valley. Gebensdorfer Horn.	Alluvioni antichi, North Italy. Alluvions anciennes (des plateaux), Rhone Valley, and Bresse district, Lyons.
Pliocene.	First glaciation.	Fluvio-glacial deposits.		Baden / Zürich. Uetliberg, Zürich.	Deckenschotter, Austrian and Bavarian Alps.

My conclusions differ from those of Dr. Du Pasquier, more especially as regards the Lorze valley-deposit, which he classes in the second, and which I class in the first glacial and interglacial period; from those of Prof. Heim as regards the moraine underlying and overlying the Lorze Nagelfluh, which moraine he refers to the Reuss, but which is more probably of the Sihl and Lorze; and lastly from those of Dr. Zollinger as regards the conglomerates of the old Kander and Simme deltas, which he refers to the second, and which I refer to the first glacial and interglacial period. Under all circumstances, the various Cavernous Nagelfluh-deposits now recognized as Pliocene—that is, Tertiary—will involve extensive alterations in the Swiss geological maps in which these deposits figure as Quaternary. For the same reason, the term 'pre-glacial' must be used in respect of three, and not of two general glaciations.

[1] The gravel-conglomerates (Cavernous Nagelfluh) are referred to as both fluvio-glacial and interglacial, because they gradually pass from one category into the other.

As regards the duration of the two interglacial periods in the Alps, Dr. Zollinger endorses the generally accepted view that the first of these periods was considerably longer than the second. By calculating the amount of deposit formed by the river Simme, and dividing this by the average annual amount of deposit by the Reuss at its inflow into the Lake of Lucerne, according to Prof. Heim's measurements, he arrives at the figure of 3000 years as the duration of the second interglacial period in the Kander Valley.[1] The approximate agreement of this figure with Heer's 2400 years for the Pleistocene lignite-deposits in the North of Switzerland is, in his view, more than accidental, that is, confirmatory of his own conclusions. But it has already been shown that the fluvio-glacial conglomerates of the Simme must be regarded as the product of the first glaciation, and not as belonging to the second interglacial period. Moreover, the proper standard of comparison with Heer's computation would be, not the gravels, but the Kander lignite-band, which would give a very small fraction of 2400 years; and, lastly, Dr. Zollinger's calculation, like all similar ones, takes no account of the enormously enhanced depositing power of torrents and rivers when in flood.

The same important factor is neglected when it is attempted to fix the duration of the first interglacial period. The assumption of a much longer duration than that of the second interglacial period rests solely upon the enormous accumulations of gravel-conglomerate in the lower Alpine valleys, pointing to a protracted process of erosion in the upper valleys; but it is much more likely that, more especially during the melting or receding of the glaciers, the rivers were in flood much more frequently, and consequently the erosion and deposition of material took place far more rapidly than in our own day. For example, if we apply the present annual rate of deposition by the river Linth (about 100 cubic metres of material per square kilometre, or 160 cubic yards per square mile of drainage-area) to the old Sihl deposit in the Lorze Valley, we arrive at the manifestly extravagant figure of 60,000 years.[2] In order to reduce it to 3000 years, or about the duration of the second period according

[1] Superficial area of Simme deposit = 6,000,000 sq. m. × 30 m. depth = 180,000,000 cub. m. Reuss drainage-area = 825 sq. kilom.; annual deposit = 150,000 cub. m. Simme drainage-area = 600 sq. kilom.; hence *pro rata* deposit = 110,000 cub. m., less 50,000 cub. m. allowance for difference of fall and precipitation = 60,000 cub. m. Hence $\frac{180,000,000}{60,000} = 3000$ years.

[2] The Linth is a more adequate criterion than the Reuss. Upper drainage-area of Sihl = 200 sq. kilom. Linth drainage-area = 600 sq. kilom.; deposit (according to Dr. Bürkli's measurements) = 60,000 cub. m. per annum. Hence Sihl deposit = 40,000 cub. m. per annum. Sihl deposit Lorze Valley 6 × 4 kilom. = 24 sq. kilom. = 24,000,000 sq. m. × 100 m. depth = 2,400,000,000 cub. m. Hence $\frac{2,400,000,000}{20,000} = 120,000$ years; $\frac{2,400,000,000}{20,000 \times 20} = 6000$ years. Even the present Sihl carries during ordinary high water in summer 400 cub. m. of water per second, or about 40 times more than its average; and torrents, when in flood, are known to carry as much as 4000 times more than their average volume.

to Heer, we must therefore assume that during the first interglacial period the rate of deposition, and hence that of erosion, was 40 times greater than it is in our own day. As has been pointed out, the formation of the Uznach lignite-deposits must have taken more than 6000 years. Hence it is reasonable to infer, contrary to the hitherto commonly accepted opinion, that the first interglacial period was the shorter, and the second the longer of the two.

However that may be, the Austrian and Bavarian Deckenschotter, the Swiss Cavernous Nagelfluh, the French 'alluvions anciennes,' and the Italian 'alluvioni antichi' constitute at the base of the Alps a belt of fluvio-glacial deposits which, being the indirect product of ice, are evidence of a first or Pliocene glaciation; while the lignites formed between two alternations of the younger morainic deposits, such as the lignites near Sonthofen in Algau, Bavaria, in the North of Switzerland, in the Kander Valley near Thun, those near Chambéry in Savoy, and those near Leffe and elsewhere in the North of Italy, besides the contemporaneous upper gravels, constitute another belt as evidence of the two subsequent Pleistocene glaciations.

For the rest, a careful and unprejudiced study of glacial and interglacial deposits in the Alps leads to the irresistible conclusion, already pointed out in the paper on the three glaciations (Geol. Mag. 1894), and also established by Dr. L. Du Pasquier and others, that every general glaciation marks a period of filling up, and every interglacial period marks a period of erosion of valleys; in other terms, that such erosion is mainly due to fluviatile, and not to glacial action.

Discussion.

Prof. Bonney expressed his sense of the value of the paper. He had had the opportunity, through the kindness of Dr. Preller, of examining several of the sections described in the paper, and could corroborate many of the statements made. There appeared to be in the neighbourhood of Zürich three separate morainic deposits with great intervening masses of stratified gravel; and he had been surprised to see how large an amount of erosion must have taken place between the deposition of the Cavernous Nagelfluh on the Uetliberg and that of the morainic deposits, some 1200 feet below it, about Zürich. But he thought that at present we could hardly attempt to correlate the Swiss and the British Glacial deposits. The former, however, were of peculiar value, because there could be no doubt that all were supra-terrestrial.

Mr. Monckton thought that the materials for the newer gravels of the Zürich district had been largely derived from older gravels or conglomerates of the Uetliberg class in the same area, and that the Uetliberg conglomerate derived its materials from the older conglomerates of the Rigi. In the same way in the South of England, materials had been passed on from older to newer gravels over and over again. In the Zürich district there was evidence of considerable differential elevation or depression since the formation of

the terraces even at low levels. At the Uetliberg there was a thick gravel now cemented into a calcareous conglomerate resting on boulder-clay, and he rather doubted whether any very great glacial extension had taken place since its formation, as in any such case the materials would probably have been re-arranged.

The Author said, in reply to Prof. Bonney's remarks, that the Pliocene age of the Cavernous Nagelfluh appeared conclusively proved (1) by the fact of its being undoubtedly older than the Pleistocene gravels, but younger than the Miocene Nagelfluh, and entirely different from both; (2) by the fact that in one case in the Kander district the younger gravel distinctly overlay the Cavernous Nagelfluh, with an intermediate layer of boulder-clay; and (3) by the analogy between the Cavernous Nagelfluh and the old Rhone, Bresse, and Italian conglomerates, in which Upper Pliocene fossils had been found. With reference to the correlation between the fluvio-glacial Nagelfluh and the plateau-gravels in the British Isles, he merely wished to suggest that, in time, some at least of these gravel-deposits would come to be recognized as being older than the lower and upper Till.

In reply to Mr. Monckton's remarks, he said that the fact that such Nagelfluh-deposits as those of the Uetliberg, Baden, and the Gebensdorfer Horn had not been swept away by subsequent glaciations appeared at first sight puzzling, but was easily explained by the well-known phenomenon, that when advancing glaciers met any serious obstacle, they either passed over it, or divided and went round it. With reference to the alterations which, as Mr. Monckton suggested, had taken place in the configuration of the hills on both sides of the Lake of Zürich at its lower end, the hills on the right or north side showed the characteristic, flat, dome-shaped outlines of the Molasse formation, and had undergone very little change; but the hills on the Uetliberg side had undergone, and were still undergoing, considerable change, owing to the river Sihl having, since the third glaciation, scooped out its present bed between the lake and the Uetliberg or Albis range, the erosion being still in active progress.

29. *The* Bajocian *of the* Mid-Cotteswolds. By S. S. Buckman, Esq., F.G.S. (Read March 20th, 1895.)

[Plate XIV.]

Note.—This paper is the third in a series by the author dealing with the Jurassic rocks, and published in the Quarterly Journal. The first, 'The Cotteswold, Midford, and Yeovil Sands,' appeared in vol. xlv. (1889), with a supplement on the 'Upper Lias of Down Cliffs' in vol. xlvi. (1890); the second, 'The Bajocian of the Sherborne District,' in vol. xlix. (1893).

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Introduction.

This essay is partly supplementary to my previous communication to the Society on the 'Bajocian of the Sherborne District,'[1] which will be alluded to as my former paper; but in the main it is entirely distinct therefrom. I divide it into three parts:—Part I. dealing with the district from Stroud to Leckhampton, and showing, among other matters, the relative extension of the Gryphite- and Lower *Trigonia*-grits; Part II. noting the discovery of an ammonitiferous horizon, thus making an addition to the Bajocian of the Cotteswolds; and Part III. giving the faunal sequence of brachiopoda in the Cotteswolds and in Dorset, so as to aid in the local correlation of strata in the former, or any other district where ammonites may be absent.

Definitions of Terms.

The following terms, which it will be necessary to use in this paper, require explanation:—

Bajocian.—In a postscript to my former paper (p. 521) it was suggested that the Bajocian might be used as 'a chronological term to coincide with the acme and paracme of the Sonninianæ,' and 'it would comprise the hemeræ *discitæ*, *Witchellicæ*, *Sauzei*, and *Humphriesiani*.' It is used in this sense in the present paper, though, as will be shown in subsequent pages, no strata deposited during some of these hemeræ are found in the district reviewed.

Mid-Cotteswolds.—In his work on the Cotteswold Hills, Lycett divided the Cotteswolds into Southern and Northern, taking the Vale of Stonehouse (the valley of the Frome) as the dividing-line (p. 7). In other cases, however, the term 'Northern Cotteswolds' seems to have been applied to the district north of the Chelt, and the term has perhaps been used somewhat loosely. For geological purposes it seems convenient to divide the Cotteswolds into three portions, and to define these districts with some precision. The following arrangement is, therefore, proposed:—That the Cotteswolds be divided into Southern, Middle, and Northern, as these divisions will be found characterized by a fair coincidence of geological and geographical features—the Southern Cotteswolds to extend from the valley of the Avon (Bath) to the valley of the Frome (Vale of Stonehouse), a district characterized by the presence of an ammonitiferous cephalopod-bed deposited during the hemeræ *opalini-striatuli*.[2] It is also distinguished by an almost complete absence of the 'intervening beds' (see p. 390), which extend very little south of the Frome Valley. Eastwards, away from the escarpment, the line between the Southern and Middle Cotteswolds might follow the road from Chalford to Siddington (Cirencester), and then, if desired, be extended along the outcrop of the Cornbrash.

Between the Mid-Cotteswolds and the Northern Cotteswolds the

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) pp. 479–521.

[2] These ammonitiferous beds extend very little north of the Frome Valley, and then some hemeræ are not represented by any deposit.

valley of the Chelt, as far as it runs, forms a convenient line of demarcation; and the geological feature is the almost complete absence of the Harford Sands. Continuing eastwards from the valley of the Chelt the northern boundary might follow the Oxford road from Andoversford as far as Little Barrington, where it might turn into the valley of the Windrush.

The Northern Cotteswolds would extend from this line of demarcation to the northern prominences of the Cotteswolds, including Ebrington Hill. The district is characterized by the development of the Harford Sands.

Although these divisions are unequal in geographical extent, their interest does not depend on that factor. In the Mid-Cotteswolds lie some of the best developments of what is called 'Inferior Oolite,' the Pea-grit being especially noticeable.

Intervening Beds.—This term is proposed, merely for brevity, in connexion with the present paper to denote all beds lying between the Upper Freestone and the Upper *Trigonia*-grit.

Bajocian Denudation.—This term is used for denudation which happened between the hemeræ *Garantianæ-Sauzei*, and was completed before the strata of the *Garantianæ* hemera were deposited.

Buckmani-*grit.*—With apologies I introduce a term which has already obtained colloquial recognition. It is intended to designate a series of strata which are sandy at Leckhampton Hill and lie between the Gryphite and Lower *Trigonia*-grits. Frequently they have been overlooked entirely, otherwise they were classed as a portion of the Gryphite-grit; but it is advisable to restrict that term to some essentially gryphæiferous beds at Leckhampton, and to their contemporaries whether gryphæiferous or not.[1] The *Buckmani*-grit is especially noted for the occurrence of *Terebratula Buckmani* and '*Terebr. Buckmaniana*.'[2] These are the most noticeable and most easily recognized fossils; they seem to be particularly confined to the grit in question. I know no other fossils which would so appropriately give their names for this purpose.

Witchellia-*grit.*—This term is to denote a series of ragstones above the Notgrove Oolite, yielding angustumbilicate *Witchelliæ* and other Sonnininæ, as well as *Terebratula Wrighti*, Davidson.

Non-sequential Strata.—The word 'unconformable' is used in two senses, and little trouble is taken to distinguish between them. Not only is it employed when strata are deposited across the upturned edges of earlier rocks, but it is also pressed into service when there is simply a deficiency in the full sequence, although the strata may be so far conformable that their planes may be practically parallel. It seems necessary to make a distinction, thus:—

[1] It may be noticed that the absence of a *Gryphæa* in other localities would not be evidence against contemporaneity with the Gryphite-grit of Leckhampton. Like the oyster, the *Gryphæa* no doubt was very dependent on local conditions, and too much sediment would be detrimental to the hatching of spat or thriving of the young.

[2] But see Appendix to Part III. 1 *e*, p. 454.

Conformable Strata.—When the sequence is complete.
Non-sequential Strata.—When the sequence is incomplete, but the planes of the deposits are practically parallel.
Unconformable Strata.—When the sequence is incomplete, and the planes of the deposits are not parallel.

Part I.

The Deposits of Bajocian Age from near Stroud to Leckhampton Hill.

In my former paper I mentioned that there had obviously been confusion between the Gryphite- and Lower *Trigonia*-grits[1]; that in the Stroud area what was really the latter had been mistaken for the former. As it is an important matter, in local as well as in more extended correlation, that the names for two non-contemporaneous deposits should not be used indiscriminately or employed the one for the other in different localities, one of the objects of this part of the present paper is to show the development of the different deposits.

If the deposits were always present no difficulty would have been experienced; but it has long been recognized that in the Stroud neighbourhood some of the 'intervening beds' were absent, and it has usually been taught that the Lower *Trigonia*-grit was the missing member. Thus Wright,[2] in dealing with Rodborough Hill, near Stroud, places 2 feet 6 inches of the 'intervening beds' as Gryphite-grit, and only 1 foot as Lower *Trigonia*-grit; but even this allowance to the latter is dissented from by Lycett in a note published by Wright in the same paper. Lycett[3] himself had, two years previously, stated that 'in the Southern Cotteswolds the series D [beds below the Gryphite-grit, namely the Lower *Trigonia*-grit] seems to have thinned out altogether,' and further (*op. cit.* p. 62) that there was 'a pause in the marine deposits during which a series of beds, 24 feet thick, were accumulated in the Northern Cotteswolds.' Lastly, Witchell[4] gives, in his general section of the vicinity of Stroud, the Gryphite-grit as the only one of the 'intervening beds,' varying from $1\frac{1}{2}$ to 12 feet in thickness. On p. 57 he says that the Lower *Trigonia*-grit does not occur in the Stroud neighbourhood, except possibly at Stroud Hill; on p. 58, that in the deposition in the Stroud area, as compared with Cleeve, there must have been a considerable pause, as about 27 feet of strata are seen at the latter place and not at the former.

These statements of Witchell and Lycett in regard to the amount missing are rather curious errors, seeing that the Lower *Trigonia*-grit, 'the missing member,' is only about 7 feet thick. They cannot have been based upon personal observation. Lycett's '24 feet' is

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 511.
[2] 'Subdivisions of Inf. Ool. in S. Engl.,' Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 44.
[3] 'Cotteswold Hills,' London & Stroud, 1857, p. 60.
[4] 'Geology of Stroud,' 1882, p. 38.

based on his acceptance of a section of Leckhampton Hill by Strickland,[1] which is certainly incorrect. Witchell's amended figure of 27 feet is founded on Wright's section of Cleeve Hill,[2] about which scepticism is very essential. Thus 27 feet are there shown above the Upper Freestone with *Chemnitzia*-grit on the top, but the *Chemnitzia*-grit Wright himself placed at the bottom in his Ravensgate section, below the Lower *Trigonia*-grit, and resting on the Upper Freestone.[3]

The necessity for clearing up misconceptions is very obvious, and this one about the Lower *Trigonia*-grit is important. When my friend the late Mr. E. Witchell showed me certain ammonites from what he called the 'Gryphite-grit of Stroud,'[4] I was able to correlate that deposit with a particular bed of Dorset.[5] I correlate it with the same bed to-day; but, with the greater precision attempted in my former paper, I can state that the deposit from which these ammonites came was laid down during the *discitæ* hemera.

That Cotteswold geologists had misunderstood the Gryphite-grit did not occur to me, and therefore I correlated that deposit all over the Cotteswolds with the same Dorset bed. During the work for my former paper the mistake was discovered: the true Gryphite-grit was of later date, the bed from which Witchell's ammonites came was the Lower *Trigonia*-grit. Thus was brought to light a serious error in the work of three Cotteswold geologists who have made the Hills their special study. This error needs correction, because it

[1] 'Cotteswold Hills,' p. 35.

[2] 'Correlation of Jurassic Rocks,' Proc. Cotteswold Nat. Field Club, vol. v. (1870) p. 143, and repeated in 'Monogr. Lias Amm.' p. 155 (Pal. Soc. 1879).

[3] Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 40.

[4] The following notes were made about eight years ago, on examination of Mr. Witchell's specimens. I am not able to check the determinations again. In certain cases I have interpreted and amended the notes in accordance with present nomenclature. The following is the transcription:—

[*Hyperlioceras*] '*Walkeri*, from Rodborough Hill and Frith Quarry; Gryphite- [Lower *Trigonia*-] grit. Several specimens.'

[*H.*] '*discoideum*. Frith Quarry; Gryphite- [Lower *Trigonia*-] grit. 1 example.'

[*H.*] '*discoideum*. Frith Quarry; a very thin variety. 2 examples. [L. *T.*-g.]'

[*H.*] '*discites*. Frith Quarry and Rodborough; Gryphite- [Lower *Trigonia*-] grit.'

'*Oppelia fusca*. *Clypeus*-grit; Stroud Hill.'

'*Sonninia adicra* [a tuberculate form aff. *Sonninia spinosa*, probably]. Frith Quarry.'

Several species aff. *Ludwigia* '*Murchisonæ*. Oolite Marl and Freestone; Frith Quarry.'

Stephanoceras of the *Humphriesianum* type. 'Gryphite-grit; Rodborough. Same form as in *Sowerbyi*-bed [Fossil Bed, *discitæ* hemera] of Bradford Abbas.'

Large *Perisphinctes* [with depressed, semilunar whorls]. *Clypeus*-grit; Stroud Hill. [Perhaps allied to '*Steph.*' *crassizigzag*, S. Buckm.]

As ammonites are scarce in the Cotteswolds, and as this list represents about twenty years' work on Mr. Witchell's part, even such a record is of service.

[5] 'Inf. Ool. betw. Andoversford, etc.,' Proc. Cotteswold Nat. Field Club, vol. ix. (1887) p. 130; Quart. Journ. Geol. Soc. vol. xlv. (1889), table facing p. 460.

affects the validity of every published list of fossils—those given by Stroud geologists must be rejected; it prevents a true understanding of the stratigraphical sequence in the Cotteswolds, while it entirely falsifies correlation with other districts and with the Continent.

Before proceeding further it will be advisable to describe the characters of the deposits in question: that is to say, of the 'intervening beds' between Stroud and Leckhampton.

The Notgrove Oolite.—A deposit of whitish oolitic limestone, generally unfossiliferous, only found at certain localities in the above district capping the Gryphite-grit, and then denuded very considerably.

The Gryphite-grit.—Ragstone-beds which yield latumbilicate *Witchelliæ*, and *Sonniniæ* of the *fissilobata-ovalis* type. At Leckhampton and other places they are very crowded with *Gryphææ*, which have a large 'wing'; but what are assumed to be contemporaneous deposits at Stroud show no *Gryphææ*, and are very sandy.

The Buckmani-*grit.*—Ragstones yielding *Terebratula Buckmani* and '*T. Buckmaniana.*' At Leckhampton they are sandy, and contain few *Gryphææ* in comparison with the Gryphite-grit.[1] At Stroud Hill some gryphæiferous beds are probably contemporaneous herewith, and not with the Gryphite-grit.

The Lower Trigonia-*grit.*—Ragstones which yield various species of Hildoceratidæ, such as *Lioceras intermedium* and *Hyperliocerata*; also *Aulacothyris Meriani*, and a very considerable number of lamellibranchiata.

It will be seen, then, that in regard to position the Gryphite-grit is above, and the Lower *Trigonia*-grit below, the deposit yielding *Terebratula Buckmani* and allies; that when ammonites are found the former furnishes Sonnininæ, and the latter Hildoceratidæ[2]; and that by the species obtained they can be correlated with different deposits of other districts, which occupy the same relative position to each other. Having placed these facts in a clear light, it will be advisable to examine the strata of the district in detail.

The sequence of strata leading up to the Upper *Trigonia*-grit is, so far as we know yet, imperfect in the Cotteswolds; and therefore the Upper *Trigonia*-grit lies non-sequentially on earlier deposits. In some cases the gap is very great. In the neighbourhood of Bath the Upper *Trigonia*-grit rests on strata which were deposited during a pre-*Murchisonæ* hemera. Coming northwards it is found to rest on strata which, from their position—palæontological evidence in the beds themselves is deficient—are considered to have been

[1] The 'Gryphite-grit' is somewhat of a misnomer, but that has always been recognized in certain localities. Such terms are useful only for local work. In more extended work the strata should be relegated to the different hemeræ; and that it is the object of this paper to do. For the hemeræ during which these deposits were laid down, see p. 421.

[2] As will be seen from the sections, the fact of the Lower *Trigonia*-grit yielding Hildoceratidæ has been confirmed at many different localities.

deposited during the *Murchisonæ* hemera; certain it is that they were laid down in a post-*opalini* hemera. Farther northwards the horizon of *Terebratula fimbria*—a species considered to have lived during the *bradfordensis* hemera—is found beneath the Upper *Trigonia*-grit. This is not far south of Stroud; and at Mount Surat, on the eastern corner of Rodborough Hill, there is the following section:—

SECTION I.—*Mount Surat.* (From Stroud, $1\frac{1}{4}$ miles nearly S.; from Leckhampton, $10\frac{1}{2}$ miles S.W. by S.)

		Feet.	Inches.
Upper *Trigonia*-grit.	1. Of this deposit 5 feet 2 inches are massive beds. *Rhynch. angulata* 3 feet 10 inches from the base of the bed; other usual brachiopods in it. '*Perisphinctes*' 4 feet 1 inch from the base, extracted. A latisulcate, peripherally nodate *Parkinsonia*, cf. *Garantiana*—like a species known at Louse Hill in Dorset, extraction hopeless	6	9
	2. Attached to the base of the bed above, a reddish-brown scale containing lamellibranchiata		$1\frac{1}{2}$
Upper Freestone.	3. Whitish oolite.		

Only $\frac{1}{2}$ mile N.W. from here is the well-known section just under the 'Fort' at Rodborough Hill. This shows a noticeable deposit intervening between the Upper *Trigonia*-grit and the Upper Freestone.

SECTION II.—*Rodborough Hill, Quarry by the 'Fort.'* (From Stroud, $\frac{3}{4}$ mile S.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	1. Hard, grey stone with numerous examples of *Terebratula globata* and *Rhynchonella hampenensis*, S. Buckm., to top of section.....	1	0		
	2. Grey, shelly limestone, with pieces of broken shells. *Acanthothyris spinosa* (Linn.); *Rhynch.* cf. *subtetrahedra, Avicula, Limea*	1	7		
				2	7
	(The parting here is not at all marked; there are several in the section much more pronounced.)				
Buckmani-grit (assumed).[1]	3. Light brown, slightly ironshot ragstone. *Ctenostreon proboscidea*, *Astarte* (cores), *Gryphæa* scarce...			1	5
Lower *Trigonia*-grit.	4. Similar bed, somewhat irregular, with lateral and vertical joints. *Serpula socialis* (Mr. Upton); *Lioceras* cf. *intermedium*, S. Buckman (9 inches from bottom of bed, 1 foot 3 inches from top of Freestone); *Gryphæa, Trichites, Pinna*, polyzoa	1	5		

[1] Mr. Upton has found *Terebratulæ* of the *Buckmani*-type, but always loose.

		ft. ins.	ft. ins.
Lower *Trigonia*-grit.	5. Earthy parting, overlying a bed similar to the above, but less fossiliferous and somewhat conglomeratic. Some broken lamellibranch-shells.	6	
			1 11
Upper Freestone.	6. Shelly, oolitic, cream-coloured limestone; flat top, with oysters; slightly bored vertically.		

Here a deposit nearly $3\frac{1}{2}$ feet thick separates the Upper *Trigonia*-grit from the Upper Freestone—a fairly rapid increase from $1\frac{1}{2}$ inches in half-a-mile. This deposit has usually been known as Gryphite-grit on the authority of Witchell,[1] and of Lycett[2]; but Wright[3] gave the lower foot as 'Lower *Trigonia*-grit,' and the rest as 'Gryphite-grit.' Both Lycett and Witchell, however, speak of the Lower *Trigonia*-grit as being absent from the Stroud area, and only developed in the Cheltenham district.

The two foregoing sections are really on the northern edge of what has been defined above (p. 389) as the Southern Cotteswolds. The next section begins the Mid-Cotteswolds; it lies across the valley, and shows that the above-mentioned gap is filled up to a certain extent, while the thickness of the 'intervening beds' increases very rapidly.

Section III.—*Stroud Hill, by the Workhouse.* (From Stroud,[4] $\frac{3}{4}$ mile E.S.E.; from Leckhampton Hill,[5] $9\frac{3}{4}$ miles S.W. by S.)

		ft. ins.	ft. ins.
Clypeus-grit.	1. Yellowish limestone somewhat broken up, partly on account of proximity to surface		6 9
Upper *Trigonia*-grit.	2. A somewhat purplish, iron-shot, rather soft, shelly stone, bored at the top. Impressions of *Trigoniæ*, also of *Parkinsonia* cf. *Garantiana*, *Rhynchonella subtetrahedra*. (This is on the horizon of Witchell's coral-bed[6]; but I found no corals.)	1 6	
	3. Hard grey limestone, with masses of brachiopoda; these are particularly well preserved in the partings, and where the bed is weathered. *Terebratula globata*, *Zeilleria Hughesi* (Walker), *Aulacothyris carinata* (Lamarck), *Rhynchonella subtetrahedra*, Davidson, *Acanthothyris spinosa* (Linn.)	5 6	
			7 0

[1] 'Geology of Stroud,' 1882, p. 55.
[2] 'Cotteswold Hills,' 1857, p. 63.
[3] 'Inf. Oolite,' Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 44.
[4] The church is taken as the centre. [5] The Camp.
[6] 'Geology of Stroud,' p. 60 and section facing p. 5.

		ft.	ins.	ft.	ins.
Notgrove Freestone, equivalent?	4. Grey, oolitic, shelly ragstone; numerous *Trigoniæ*, their tests replaced by decomposed iron oxide; also smooth Pectens. The bed is bored considerably at the top			1	2
Gryphite-grit, contemporary deposit.	5. Greyish arenaceo-calcareous ragstone, weathering brown, on the whole rather bare of fossils. In some places it is rather shelly—the bottom bed contains many shell-fragments. *Acanthothyris* aff. *Crossi*, Walker, was found about 3 feet down, scarce; and a block 3 feet 4 inches down yielded a few specimens, also a coarsely clavellate *Trigonia*,[1] *Astarte elegans*, *Ostrea*, and other lamellibranchiata—impressions or fragments			5	9
Buckmani-grit.	6. Sandy, somewhat oolitic, somewhat shelly stone. Numerous *Gryphææ* in partings, Belemnites, smooth Pectens; visible.....	3	4		

Section III a.—*Below the road to Bisley, right-hand side. The Coneygre Quarry.*

		ft.	ins.	ft.	ins.
	7. Grey, sandy stone, with *Gryphææ* fairly abundant[2]	1	0		
	8. Yellowish, sandy stone.....	2	6		
	9. Rather soft, yellow, sandy stone.....		8		
	10. Sandy stone, variable in thickness, 6–8 inches		7		
	11. Clayey marl-parting, variable in thickness, 2–8 inches		5		
	12. Sandy stone, with occasional *Gryphææ*	1	8		
				10	2
Lower *Trigonia*-grit.	13. Yellowish-grey, somewhat ironshot ragstone, with occasional *Gryphææ*, *Hyperlioceras Walkeri*, S. Buckm., 1 foot 8 inches from base[3]			2	9
Upper Freestone, equivalent.	14. White oolitic stone. *Terebratula fimbria*. ('I found lying about several specimens of *Terebr. notgroviensis*,' Mr. C. Upton, *in litt.*, June 13th, 1894. [These would be from here or lower.])				

[1] Not unlike *Trigonia signata*, Ag. (Lyc.).

[2] The matrix is rather different from that of the bottom beds in the workhouse quarry. There may be a gap here.

[3] *Subsequent Note.*—'In the L. T. G. [Lower *Trigonia*-grit] I found a rather nice specimen of what I take to be *H.* [*Hyperlioceras*] *discites*, or something akin to it, about 18 inches from the top of the Upper Freestone; and above that, in a bed which has a somewhat sandy character [probably bed 11], indications of *Terebratula Buckmani*.'—Mr. C. Upton, *in litt.*, June 13th, 1894.

Bed 4 was probably laid down contemporaneously with the Notgrove Freestone,[1] a deposit which overlies the Gryphite-grit at Leckhampton (see later, p. 410). My interpretation of bed 5 is that it was a sandy deposit really contemporaneous with the Gryphite-grit of Leckhampton, although containing no *Gryphææ*; and that beds 6 & 7 may really be contemporaneous with the upper beds reckoned as *Buckmani*-grit at Leckhampton, although they contain many more *Gryphææ*. It must be remembered that *Gryphææ* are very bad guides, because local sandy conditions would prevent them from thriving. For this reason they were scarce at Leckhampton during the deposition of the *Buckmani*-grit, and scarce at Stroud during the deposition of the Gryphite-grit. The term 'Gryphite-grit' must be used, not for a bed containing *Gryphææ*, for there are many such; but for any deposit contemporaneous with *the* gryphæiferous beds of Leckhampton, whether such deposit contain *Gryphææ* or no.

In regard to the Stroud section, it may be noticed that *Hyperlioceras Walkeri* and *H. discites* have been found at about the same level as a near ally, *Lioceras* cf. *intermedium*, at Rodborough. All of these species belong to the family Hildoceratidæ, which did not survive the *discitæ* hemera.

It may be remarked that Mr. E. Witchell placed 12 feet of strata between the Upper *Trigonia*-grit and the Upper Freestone at Stroud Hill[2]; this thickness is, however, too small. He assigned it all to Gryphite-grit, but suggested that the lower part might represent the Lower *Trigonia*-grit.[3]

A similar thickness of beds is shown on the other flank of this ridge, namely at Swifts Hill, the locality memorable for the sad death of Mr. E. Witchell while engaged in his favourite pursuit. It gives the following section:—

Section IV.—*Swifts Hill.* (From Stroud, $1\frac{3}{4}$ miles N.E.; from Leckhampton Hill, 8 miles S.W. by S.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	1. Ragstone with *Terebratula globata*, *Rhynchonella subtetrahedra*, and *Trigoniæ* ..... about			5	0
Notgrove Freestone.	2. Bluish-grey ragstone, much stained with iron and bored vertically. Thickness variable, 2″–7″.....	5			
	3. Grey ragstone, slightly shelly.....	11			
				1	4
Gryphite-grit.	4. Hard, grey, sandy ragstone, some beds shelly, some not; *Gryphææ* in partings, more frequent in lower part.....			7	0[4]

[1] A fragment (body-chamber) of a rather latumbilicate *Witchellia* found by Mr. Charles Upton on the rubble-heap of the quarry, with similar matrix, supports this view.

[2] 'Geology of Stroud,' section facing p. 5. [3] *Ibid.* p. 57.

[4] Perhaps some of this should be *Buckmani*-grit, as interpreted at Leckhampton.

		ft.	ins.	ft.	ins.
Buckmani-grit.	5. Sandy ragstone, mostly very shelly. In places beds with numerous small lamellibranchiata in an intractable matrix. The bottom of this bed is very uneven	5	0		
	6. Fine yellow sand—a marked horizon in the quarry	4″–6″			
	7. Purplish-grey argillaceous mud, with numerous broken shells. *Terebratula Buckmani*, Dav., but scarce	3″–6″			
	8. Shelly grey ragstone, bored in places. At the very top of this bed *Acanthothyris*, n. sp., feebly spinose	1	6		
				7	3
Lower *Trigonia*-grit.	9. Yellowish, somewhat ironshot, shelly ragstone, with a few lamellibranchiata; much bored in places. *Rhynchonella balinensis*, Szaj	5	0		
	10. Yellowish marl, with enclosed white pebble-shaped humps		4		
				5	4
Upper Freestone equivalent, and Oolite Marl.	11. Oolitic débris		5		
	12. White oolitic limestone	3	2		
	13. Brown marl		1		
	14. Greyish marl with *Rhynch. Tatei*, *Rhynch.*, sp., *Terebr. fimbria* (scarce), *Trigonia*, sp.		9		
	15. Yellow argillaceous mud		1		
				4	6
	16. White shelly oolite.				

At Stroud Hill about 10 feet, or perhaps more,[1] separated the Notgrove Freestone and the Lower *Trigonia*-grit. Here the thickness is 14 feet, with *Gryphæa* towards the top; the latter fact rather supports the suggestion about the Stroud Hill beds.

The following is a section of the Frith quarry,[2] near Painswick, whence Witchell obtained several ammonites indicative of the *discitæ* hemera. I have also obtained a poor ammonite therefrom.[3] For the section from beds 1 to 24 the present writer is responsible; but the details of the beds below 24 are copied from a section of the quarry made by Mr. Upton, which he kindly placed at my disposal. Mr. Upton has obtained a fine specimen of *Hyperlioceras discites* from this quarry, thus confirming Witchell's finds. The specimen was not *in situ*, but was lying in a part of the quarry where it could only have come from beds 8–11.

[1] On account of the uncertain extent of the gap between the Workhouse and the Coneygre quarries.

[2] No name on the Ordnance Survey map; it is close to Wick Street.

[3] It is nearest to the *Lioceras intermedium* represented in pl. xi. figs. 2, 3, 'Monogr. Inf. Ool. Ammonites,' Pal. Soc. vol. xli. (1888).

Section V.—*The Frith Quarry.* (From Painswick, 1 mile S.; from Stroud, 2 miles N.N.E.; from Leckhampton Hill, 8 miles S.W. by S.)

		ft.	ins.	ft.	ins.
Buckmani-grit.	1. Ragstone, about	2	0		
	2. Yellowish sandy ragstone,[1] about	3	0		
	3. Hard, yellowish, sandy ragstone. Large double-valved *Cucullæa* showing. Bottom of the bed very uneven		10		
	4. Fine, bright yellow sand		6		
	5. Grey, earthy marl		2		
	6. Yellowish, shelly ragstone; some *Gryphææ*. Young specimen of *Terebratula Buckmani* at the base. *Acanthothyris*, sp., at the very top.[2] (*Hyboclypus caudatus*, Wr.: and corals, Mr. Upton.)	2	0		
				8	6
Lower *Trigonia*-grit.	7. Brown earthy marl		3		
	8. 'Lamellibranch-bed.' Yellowish, ironshot ragstone, rather soft and considerably broken up by the weather. *Pholadomya fidicula, Trigonia costata, Trigonia formosa, Isocardia cordata, Opis cordiformis*, Lyc., *Cucullæa* cf. *ornata, Ostrea Marshi, Cypricardia*; *Lioceras* cf. *intermedium* 1 foot from the top.[3]	1	9 to 2 ft.		
	9. Soft yellowish stone		4		
	10. Yellowish ironshot stone similar to Bed 8, with corals. Not continuous in the quarry		3		
	11. Similar stone with *Gryphæa* and *Gresslya gregaria* (?)		9		
	12. Brown earthy marl		4		
				3	8
Upper Freestone and Oolite Marl.	13. Soft whitish oolitic marl. In this bed are large angular pieces of a hard, cherty, purplish bed, apparently remains of a bed broken up and redeposited		7		
	14. Marl parting		2		
	15. Yellowish limestone. (This and the bed above do not seem to be continuous.)		2		
	16. Disintegrated band		1		
	17. Coarse, yellowish limestone		3		

[1] Beds 1 and 2 are inaccessible, and bed 3 is practically so, though pieces are shown in the soil on one side. The details here given were taken from a fallen block, which could be identified by its uneven base and the sand adherent to it.

[2] Later information:—'At the Frith I found two or three lumps of the sandy limestone which had fallen from the sandy beds above the L. T. G. [Lower *Trigonia*-grit] and knocked out several small *T*[*erebratula*] *Buckmani*, two specimens very like diminutive *T. Phillipsiana*, about 1 inch in length, and one small spinose *Rhynchonella*.'—Mr. C. Upton, *in litt.*, May 14th, 1894.

[3] Witchell's ammonites came, no doubt, from this bed. See p. 392.

		ft.	ins.	ft.	ins.
	Brought forward	1	3		
Upper Freestone and Oolite Marl.	18. Whitish, oolitic, crumbly limestone with *Rhynchonella cynomorpha*, sp. n.,[1] abundant throughout	1	10		
	19. Brown earthy band with numerous fragments of shells		2		
	20. White chalky limestone	2	6		
	21. Brown earthy band		3		
	22. Whitish limestone much broken up, with *Terebratula fimbria*; and with *Rhynchonella Tatei* in the lower 3 or 4 inches	1	0		
	23. Yellow marl, with *Rh. Tatei* very abundant		4		
	24. Pale marly limestone crowded with large *Terebratula fimbria*. *Rh. Tatei* at top	1	0		
	25. White, chalky-looking limestone, broken up	1	6		
	26. White marl, rather hard at the top, but softer at the bottom, with immense numbers of *Terebratula fimbria* in the lower 12 inches	3	0		
	27. Pale grey limestone, hard but fragmentary—few fossils.....	6	6		
	28. White limestone, hard at top, marly at bottom; a few *Terebr. fimbria*...	1	0		
	29. Yellowish marly limestone with small *Terebr. fimbria*; and with *Rhynchonella subobsoleta* throughout, but not abundant	2	6		
	30. Yellowish marl with *Rh. subobsoleta*, *Terebr. submaxillata* (fairly abundant), *T. curvifrons* (scarce), and *Waldheimia Leckenbyi*	1	8		
				24	6
Lower Freestone.	31. Oolitic stone, unfossiliferous, with smooth waterworn upper surface exposed ..... about	12	0		
				12	0

If the section at the Frith be compared with that of Swifts Hill the Lower *Trigonia*-grit is found to be rather thinner. The horizon of *Terebratula Buckmani* is at about the same level above the Lower *Trigonia*-grit; and the same bed of yellow sand is persistent, as will be found in many subsequent sections for some miles. Above the *Buckmani*-grit the beds have been removed by Quaternary denudation.

About $\frac{3}{4}$ mile north-east Bull Cross shows a small opening in a somewhat tumbled condition. The Lower *Trigonia*-grit is recognizable, and about 4 feet thick. The next available exposure is about 2 miles farther on, situated on the brow of the hill overlooking Sheepscombe, and nearly due east thereof. It is quite a small, and apparently a temporary opening.

[1] See p. 452.

Section VI.—*Sheepscombe.* (On the hill-flank towards Bitfield Farm. From Stroud $4\frac{3}{8}$ miles N.E.; from Leckhampton Hill $5\frac{1}{2}$ miles S.W. by S.)

		ft.	ins.
Upper *Trigonia*-grit.	Shelly ragstone, *Terebratula globata, Rhynchonella* cf. *subtetrahedra*	2	6
Gryphite-grit.	Oolitic ragstone in several beds, with numerous *Gryphææ*, in partings, going right up to the Upper *Trigonia*-grit	3	3

There is here no sharp plane of lithological demarcation between the Upper *Trigonia*- and Gryphite-grits. Of the latter several beds are bored, but the top very little so.

There is a very noticeable deposit of Gryphite-grit in this quarry, without any Notgrove Freestone to separate it from the Upper *Trigonia*-grit.

Standing by itself this section would give little information; but it may be readily interpreted by means of the sections at Kimsbury Castle, which lies 2 miles N.W. by W. It is advisable, therefore, to go back and take up openings on the outer ridge of the Hills.

At Selsley Hill, about 2 miles S.W. by W. of Stroud, no deposit separates the Upper *Trigonia*-grit and the Upper Freestone. I have not visited the hill lately, but Mr. Upton allows me to quote him as an authority for this fact. It is quite possible that the same want of intervening strata obtained farther northwards; but the Valley of the Frome cuts the Oolite beds here; and it is about $2\frac{1}{4}$ miles before the next exposure of beds superjacent to the Upper Freestone is found. This is above Randwick, where the following incomplete and unsatisfactory section was obtained:—

Section VII.—*Above Randwick.* (Disused quarry at the parting of the lane to Ruscombe. From Randwick Church, about 500 yards N.; from Stroud, $1\frac{3}{4}$ miles N.W.)

		ft.	ins.
Buckmani-grit.	Greyish-yellow sandstone, with a few *Gryphææ*, *Acanthothyris*, sp., globose. The upper part laminated, composed of coarse grains and small bits of broken shells cemented together	7	0
Lower *Trigonia*-grit.	Slightly ironshot brownish stone		4
	Ironshot marl with *Ostreæ*, *Terebratula*, sp., *Rhynchonella*, sp.		3
Upper Freestone.	White, oolitic, rather laminated freestone—a few feet visible.		

One noticeable point about this section is that I was only able to consider about 7 inches as representing the Lower *Trigonia*-grit.

As the Upper *Trigonia*-grit was not found, the thickness of the 'intervening beds' is probably understated. There may have been more above the 7 feet here shown, although $2\frac{1}{2}$ miles south, at Selsley Hill, are no 'intervening beds.' About $\frac{3}{4}$ mile N.N.E. occurs the next exposure, also unsatisfactory, but useful for comparison.

SECTION VIII.—*Bird-in-Hand, near Whiteshill.* (From Stroud, 2 miles N.N.W.)

Upper *Trigonia*-grit overlying brown shelly stone with *Acanthothyris*, small globose species. Blocks of a yellowish, somewhat shelly sandy stone are lying about, and these have come from lower down. It is safe to say that there are some 4 or 5 feet of this bed worked which would appear to be similar to that noted at Stroud Hill below the Upper *Trigonia*-grit. In that case these sandy beds would be superior to the upper beds shown in the next section—to agree with Stroud Hill.

SECTION IX.—*Scotesquar*[1] *Hill.* (From Stroud, 2 miles 2 furlongs, nearly N.; from Leckhampton, 8¼ miles S.W.)

		ft.	ins.	ft.	ins.
Gryphite-grit?[2]	1. Grey, shelly, sandy stone, with fairly numerous *Gryphææ* ..... about			6	0
Buckmani-grit.	2. Greyish-yellow, shelly, sandy stone ..... about	3	0		
	3. Yellow sands.....		8		
	4. Grey marl		4		
	5. Yellowish sandy stone	1	6		
				5	6
Lower *Trigonia*-grit.	6. Yellow, ironshot, oolitic stone, somewhat marly ..... about			3	6

The above rests on whitish marl cemented by calcareous infiltration.

Note.—The section is a shallow opening on the side of the hill. The beds have evidently been much affected by shifting, and from this exposure alone the sequence could not have been made out.

This section, placed below the estimated amount of sandy beds at the Bird-in-Hand, gives about 19 feet of the 'intervening beds,' a thickness which corresponds closely enough with that of Stroud Hill, about 20 feet.

From the ridge running by Spoonbed all beds later than the Lower Freestone have been removed, and so there is no exposure until Kimsbury Castle, 2¼ miles N.E. by N. There is a fine quarry on the eastern flank of the hill overlooking Castle Godwyn, showing the Gryphite- and *Buckmani*-grits side by side on account of a fault, so that some caution is required in making this section. The Lower *Trigonia*-grit supporting the grey marl wherein *Terebratula Buckmani* is generally found, and the overlying sand, are seen on the top of a deep freestone-quarry immediately to the right of the lane leading from above Castle Godwyn on to the hill. The beds are disturbed, and the measurements, therefore, may not be quite trustworthy; for instance, as regards the small thickness of

[1] Spelt on the Ordnance Survey map as 'Scotchguar;' but 'skort' or 'scote' is a common Gloucestershire word reasonably applied in some of its various meanings to this quarry. It is the Anglo-Saxon '*Sceótan*.' On the meanings of 'skort' see the Gloucestershire Glossary. 'Guar' is obviously a misconception of 'quar' (kwar), the dialect form of 'quarry.'

[2] Compare *Buckmani*-grit, Stroud Hill, bed 6, p. 396.

1 foot allotted to the Lower *Trigonia*-grit. Again, between these two sections (A & B) there may be a gap—though it cannot be much, or the beds tabulated may be fairly correct in sequence without hiatus. The following gives the results obtained:—

SECTION X.—*Kimsbury Castle.* (From Stroud, $4\frac{1}{4}$ miles N. by E.; from Leckhampton Hill, $5\frac{3}{4}$ miles S.W. by W.)

		ft.	ins.	ft.	ins.
	A. *East side of the Hill.*				
Upper *Trigonia*-grit.	1. Grey, shelly stone. *Terebratula globata, Rhynchonella hampenensis, Trigonia*			5	0
Notgrove Freestone.	2. Slightly ironshot, greyish with pink tinge, oolitic stone. Considerably bored at the top, and with excavated pockets filled with earthy mud in one of which *Terebr.* cf. *globata* was found—evidently a case of subsequent deposition. The top of the bed is planed off flat, and oysters are adherent thereto		8		
	3. Somewhat disintegrated oolitic beds.		7		
	4. White oolitic freestone, somewhat bored by large annelids		9		
	5. Disintegrated oolitic debris		4		
	6. Yellowish-white oolitic stone bored in many places by large annelids		6		
	7. Oolitic paste		4		
	8. Similar to 6		10		
			—	4	0
Gryphite-grit.	9. Whitish oolitic bed with *Gryphæa*. It is considerably bored		10		
	10. Oolitic paste, with broken shells of *Gryphæa*		2		
	11. Oolitic ragstone with *Gryphæa*, some very fine with large 'wings.' To some of them polyzoa are attached both inside and outside. About four beds, with earthy partings, nearly all the beds being bored more or less by annelids	4	6		
				5	6
Buckmani-grit.	12. Grey, sandy, non-oolitic beds without marked partings. Occasional *Gryphæa*	5	0		
	13. Yellow, sandy stone in several beds.	6	0		
	14. Hard, grey, very shelly stone	2	0		
	B. *South-east side of the Hill.*				
	15. Grey, sandy stone, with occasional *Gryphæa* about	2	6		
	16. Seam of bright yellow, siliceous sand		3		
	17. Grey, argillaceous, shelly marl; *Terebratula* cf. *Buckmani* crushed		1		
	18. Pinkish-grey sandy stone; costate *Trigoniæ* and *Serpulæ*		7		
	19. Grey, sandy, shelly stone, with corals, *Ostreæ, Serpulæ*	1	0		
				17	5

		ft.	ins.	ft.	ins.
Lower *Trigonia*-grit.	20. Brown marl		1		
	21. Hard, brown, ironshot, shelly stone.		4		
	22. Brown ironshot marl		7		
				1	0[1]
Upper Freestone equivalent.	23. White chalky débris ..... about			8	0
	24. Brownish, coarsely oolitic stone in large masses			6	0
	25. Similar stone, more broken up, *Terebratula fimbria*			1	2
Oolite Marl.	26. Brownish, sometimes quite white chalky paste. *Terebratula fimbria* common, but poor				4
	C. *South side of the Hill.*				
'Lower Freestone.'[2]	27. Fine, white, oolitic freestone; deep quarry ..... Thickness about			40	0
	28. Whitish, shelly, massive stone			2	6
'Pea-grit.'	29. Brown marl, *Rhynch.* cf. *subobsoleta.*				3
	30. Whitish pisolitic stone: *Nerineæa, Zeilleria* cf. *Leckenbyi*			3	10
	31. Brown, pisolitic marl, very crumbly; crushed brachiopoda			1	1
	32. Whitish oolitic stone, *Nerinæa, Trigonia, Lima*			1	1
	33. Crumbly pisolitic marl, *Rhynchonella subangulata* very common, mostly crushed; *Terebratula* cf. *fimbria*...				10
	34. Grey pisolitic stone, visible			1	3

When the small section at Sheepscombe (VI., p. 401) is compared with this one it is impossible to say, from the beds themselves, whether the Gryphite-grit exposed thereat represents the bottom or top of the Gryphite-grit of Kimsbury Castle. It has been taken as representing the bottom, entailing the assumption that the Notgrove Freestone and the rest of the Gryphite-grit have been removed by Bajocian denudation. This is supported by the fact that if the 'intervening beds' shown at Kimsbury Castle be plotted to scale, and a line drawn from them to Bull Bank, Miserden, where there are no 'intervening beds,' such a line passes through Sheepscombe, and indicates that it should possess few if any beds of the Gryphite-grit.

Continuing in the same direction as before, a section is found in Buckholt Wood; I am indebted to my friend Mr. Charles Upton for drawing my attention to it. As this section is necessary for the interpretation of a section on the other line taken, namely Dunley, it will now be convenient to join the two routes and describe the remaining sections in their order across country. The chief feature of the Buckholt Wood section is a good development of the *Buckmani*-grit overlain by a little Gryphite-grit.

[1] The disturbed character of the beds makes this thickness very uncertain. There may be more beds belonging to the Lower *Trigonia*-grit hidden by the overslip.

[2] Some of this may be contemporaneous with the lower part of the Oolite Marl of other places.

SECTION XI.—*In Buckholt Wood.*[1] (From Stroud, $5\frac{3}{8}$ miles N.N.E.; from Leckhampton Hill, $4\frac{3}{4}$ miles S.W.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	1. Shelly ragstone with characteristic fossils in a small opening just behind the quarry, and also shown (about 1 foot) at top of quarry (right-hand side) ..... altogether about			1	8
Gryphite-grit.	2. Greyish-green, oolitic, sandy ragstone. Small, smooth Pectens rather numerous, *Gryphæa* (scarce) in upper third. *Astarte elegans* common, *Trigonia* (clavellate sp.) in lower third. On quarry-heap (pieces recognized by being stained with reddish soil) *Acanthothyris* and impression of spinous *Sonninia* ...			3	2
Buckmani-grit.	3. Grey sandy stone weathering yellow; '*Terebratula* cf. *Buckmaniana*' (broadish small form) nearly at top (*T. Buckmani* in upper part; Mr. Upton)	4	0		
	4. More or less incoherent sandy parting with some stone. *Ctenostreon proboscideum* (?)		4		
	5. Hard grey sand-rock, containing shells, but often only fragments—chiefly lamellibranchiata, extraction rather hopeless. *Gryphæa* occasionally. At the top of the bed, where it is rather softer owing to weathering: *Terebratula Buckmani*; *T.* allied form, but too broad, with too pronounced a fold, for true *T. Buckmani*; *Acanthothyris* sp.; also a biplicate *Terebratula* found close to this horizon in a matrix suggesting this position	1	10		
	6. Yellow, incoherent sand, of variable thickness owing to irregularity of under and upper surfaces of over- and underlying beds. From 1 foot 3 inches to 2 feet. ..... Average	1	8		
	7. Similar to No. 5	1	0		
	8. Yellowish-brown sand at top, greyish marly sand below	1	3		
	9. Pinkish-grey sand-rock	1	3		
				11	4
Lower *Trigonia*-grit (?)	10. To the bottom of the quarry obscured by fallen débris, about			2	6

A genuine young specimen of *Terebratula Buckmani*, from a sand-bed, was found on the spoil-heap.

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[1] This is marked as Cranham Wood in the Ordnance Survey-map; but what is there marked Buckholt Wood is Cranham Wood, and *vice versa*. This particular Buckholt Wood must not be confused with another locality of the same name S.W. of Stroud, to which I have often referred in other writings.

The next section is that of a quarry called Dunley—a rather out-of-the-way place, not easy to find. It shows that the Gryphite-grit is wanting—that the Upper *Trigonia*-grit is in contact with the *Buckmani*-grit; and assuming that Bed 4 of Dunley is rightly correlated with Bed 4 of Buckholt Wood, it will be noticed that the upper part of the *Buckmani*-grit has been removed. The marks of the denudation which preceded the deposition of the Upper *Trigonia*-grit are very noticeable in this quarry.

Section XII.—*Dunley Quarry.* (From Stroud, 5½ miles N.E. by N.; from Leckhampton Hill, 4¼ miles S.W. by S. Situated to the right of the by-road from Foston's Ash[1] to Cranham Common, where this meets the by-lane which leaves the main road from Birdlip, just before Hazel Hanger Wood.)

		ft.	ins.	ft.	ins.
Between *Clypeus*- and Upper *Trigonia*-grits.	1. White, oolitic stone, broken up and mixed with soil			2	0
Upper *Trigonia*-grit.	2. Grey shelly ragstone with earthy partings, containing brachiopoda in good preservation. *Terebratula globata, Rhynchonella hampenensis.*			4	0
Buckmani-grit.	3. Grey, pinkish, hard, sometimes shelly, at other times oolitic stone, in two beds. The upper surface planed off, with pockets. The top bed much bored, in places right through, and the under one often pierced. There are in places iron stains and impressions of *Trigoniæ*—the shells decomposed, the cavities filled with iron oxide	2	0		
	4. Grey sandy parting; the presumed horizon of a specimen of *Terebratula Buckmani* from a sandy matrix picked up from the spoil-heap. It is not easy to get at, being close to the floor of the quarry and hidden by rubble	0	2		
				2	2

Besides the *Terebratula Buckmani* noted above, the spoil-heaps yielded *T. globata, Zeilleria Hughesi*, and a broad form; *Aulacothyris carinata*, feebly sulcate; *Rhynchonella hampenensis*, common; *Rh. angulata, Rh. subtetrahedra*; and *Acanthothyris spinosa*: all except *T. Buckmani* are indicative of the Upper *Trigonia*-grit.

There are two sections in Cranham Wood ('Buckholt'), one on the right-hand side of the road from Birdlip to Painswick, the other on the right-hand side of the road from Birdlip to Foston's Ash. They are only a short distance apart, and both show the same features. The following is a section of the last-mentioned quarry:—

[1] Incorrectly spelt 'Foster's Ash' on the Ordnance Survey-map.

SECTION XIII.—*Quarry in Cranham Wood.*[1] (On the right-hand side of the road from Birdlip to Foston's Ash. From Birdlip, 1 mile.)

		ft.	ins.
Upper *Trigonia*-grit.	1. Grey, shelly ragstone. *Terebratula globata, Rhynchonella angulata*	3	0
	2. Disintegrated earthy band, to be seen on the west side of the quarry about 3 inches thick, but not on the south side		
Upper Freestone.	3. White, oolitic, shelly freestone, *Terebratula fimbria*, very plicate forms, not uncommon at 4 feet 6 inches from top of bed; also at 4 feet, and at 3 feet 6 inches down. Top of the bed much bored by annelids, and occasionally by *Lithodomi*	6	0

Note.—A few specimens of *Rhynchonella cynomorpha*, n. sp., were found on the spoil-heaps, but their exact horizon could not be fixed. They come, of course, in the Freestone, either with or just above *Terebratula fimbria*. (Compare section of the Frith, p. 400.)

The remarkable thing about this quarry is that not only are all the 'intervening beds' absent, but the Upper Freestone itself has been denuded away to a certain extent.[2]

Three-quarters of a mile farther north is another section—that of Buckle Wood. In it the Upper Freestone seems to have suffered less from denudation, for there is as much as 4 feet 6 inches exposed, and yet no bed with *Terebratula fimbria*. The inference is that the maximum of the Bajocian denudation was reached at Cranham Wood quarry.

SECTION XIV.—*Buckle Wood Quarry.*[3] (From Birdlip, 3 furlongs on the left-hand side of the road to Stroud. From Stroud, 6 miles 5 furlongs N.E.; from Leckhampton Hill, 3 miles S.W. by S.)

		ft.	ins.
Upper *Trigonia*-grit.	1. 'RAGSTONE; WILL STAND FROST.' Grey shelly limestone with *Terebratula globata, Rhynchonella hampenensis, Zeilleria Hughesi*, etc., and with *Rhynchonella angulata* as a common fossil ..... about	4	0
Upper Freestone.	2. 'FREESTONE; WILL NOT STAND FROST.' White shelly oolitic stone.....	4	6

Note.—The Upper Freestone is bored a little at the top. Shelly stone with several specimens of *Terebratula globata* occurs, in close contact therewith, parted by a seam of marl; but there are more conspicuous seams above. Freestone-lumps are on the same horizon as the shelly stone, so that this bed is evidently

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[1] Marked as 'Buckholt Wood' on the Ordnance Survey-map; see p. 405.

[2] It must be remembered that there was denudation of the Upper Freestone before the deposition of the Lower *Trigonia*-grit; such denudation presumably took place during the *concavi* hemera, and during the deposition of the Harford Sands in the Northern Cotteswolds. In the present case a later denudation has not only removed the subsequently-deposited 'intervening beds,' but seems to have cut the Upper Freestone itself down to a still lower level.

[3] Buckle Wood is distinct from Buckholt Wood; but perhaps a confusion between the two names misled the officers of the Ordnance Survey. Buckle Wood is in the parish of Brimpsfield; it is not marked on the 1-inch map.

somewhat conglomeratic. From the top beds—so the workmen said—was obtained a specimen of *Pleurotomaria* cf. *actinomphala*. A fragment of *Lytoceras* aff. *Eudesianum* was found on the spoil-heap. Both these finds are curious because, from the position of allied forms in Dorset, they would be expected to characterize beds of the *Sauzei* or *Humphriesiani* hemeræ.

The celebrated locality of Birdlip is reached 3 furlongs farther on; but the place is disappointing. The best exposures have been fenced in for private gardens, pleasure-grounds, and the like. An exposure in Whitcombe Wood is somewhat overgrown and obscured. The sections show the Upper *Trigonia*-grit resting on Upper Freestone. About 3 feet of unfossiliferous beds separate the Upper *Trigonia*-grit from the *Clypeus*-grit—the latter a very distinct rock, rubbly, iron-stained, containing soft marly patches, with large *Terebratula globata*, *T. birdlipensis*, and *Clypeus Ploti*.

Two-and-a-half furlongs from Birdlip — continuing the same general line—is Cuckoo Pen Quarry. Here the 'intervening beds' are once again met with. They are about 3 feet thick, all presumably belonging to the Lower *Trigonia*-grit. The following section was noted:—

Section XV.—*Cuckoo Pen Quarry.* (From Birdlip, 2½ furlongs on the right-hand side of the road to Cheltenham; from Stroud, 7¼ miles N.E.; from Leckhampton Hill, 2 miles 3 furlongs S.W. by S.)

		ft.	ins.
Upper *Trigonia*-grit.	1. Grey, shelly stone. *Terebratula globata, Rhynchonella hampenensis, Trigoniæ*	2	0
	No sign of a distinct parting.		
Lower *Trigonia*-grit.	2. Ironshot marly ragstone. Small *Gryphææ, Ctenostreon proboscideum* (?), *Limæ, Serpulæ*, corals	3	2
Upper Freestone.	3. White oolitic freestone capped by a hard pinkish limestone ..... visible	7	0

From Cuckoo Pen to the next quarry, Tuffley's, is ¾ mile. Here the thickness of the intervening beds is increased nearly 6 feet by the addition of the *Buckmani*-grit; but it will be seen that, while the lower part of this grit is of the usual thickness, the upper part is deficient in that respect. It is, therefore, removal of the upper part, and not attenuation of the whole bed, which accounts for the want of thickness of the *Buckmani*-grit. This is an important fact; but it fits in exactly with what has been observed in the sections given in these pages, both approaching and leaving Birdlip.

Section XVI.—*Tuffley's Quarry, by the Air Balloon.* (On the left-hand side of the road from Birdlip to Cheltenham; from Stroud, 8 miles N.E.; from Leckhampton Hill, 1¾ miles S.W. by S.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	1. Grey, shelly ragstone, numerous shells. *Rhynchonella hampenensis*, S. Buckm., *Rh. angulata*, Dav., *Zeilleria Hughesi*, Walker, *Pecten lens*, *Limea*, etc.; to top of quarry ..... about			4	0

		ft.	ins.	ft.	ins.
Buckmani-grit.	2. Grey, sandy, shelly ragstone, weathers yellow. The top is very uneven, and the upper part excavated into deep pit-like holes; average	1	8[1]		
	3. Bright yellow, incoherent sands (like Cotteswold Sands), occasionally hardened, especially the lower part.	1	7		
	4. Brown and blue, stiff clayey marl, with numerous shelly and nacreous fragments		6		
	5. Grey sandy marl containing in places large nodular-shaped lumps, and in other places indurated into a stone-like band; where soft, *Terebratula Buckmani* may be readily extracted		10		
	6. The 'Clay Bed.' 'The Serpula-bed.' Hard pinkish-grey ragstone with uneven top. *Serpula socialis* abundant	1	4	5	11
Lower *Trigonia*-grit.	7. The 'Marl-Bed or Marly Ragstone.' Ironshot marly stone with occasional *Gryphæa* and various lamellibranchiata			3	0
Upper Freestone.	8. The 'Pendlum-Bed.' Whitish shelly limestone, hard and sometimes blue-centred	2	0		
	9. The 'Iron Bed.' Pinkish, somewhat smooth-feeling limestone. 'The hardest bed of all to get out' (quarryman), *Nerinæa*, corals, and some shells	1	3		
	10. The 'Lower Pendlum-Bed.' Hard blue-centred limestone in several layers	3	0		
	11. On the other side of the road there may be seen about 4 feet more of the limestone-bed. The beds from 8 downwards are the equivalent of the Upper Freestone of geologists.	4	0	10	3

Note.—Mr. Charles Upton informs me that he has found *Aulacothyris Meriani* (Oppel) in this quarry on the spoil-heap. My efforts to discover it *in situ* have failed; but this find is noticeable, because this is the first locality, coming from Stroud, for which it can be recorded. He has also obtained a globose *Acanthothyris* identical with the form obtained at Charlton Common in the *Buckmani*-grit; see later, p. 413.

Another mile and three-quarters in the same direction brings us to the classical locality of Leckhampton Hill. Here the *Buckmani*-grit is fully developed, because it is capped by the Gryphite-grit; this bed is also not in any way denuded, because above it lie some 2 feet of Notgrove Oolite. Now the last point at which the Notgrove Oolite was seen, by the route taken, was Kimsbury Castle, 6 miles distant; and the Gryphite-grit was last observed in Buckholt Wood, $4\frac{1}{2}$ miles away. The thickness of these and other beds at Leckhampton is given in the following section:—

[1] The manner in which the Upper *Trigonia*-grit is dovetailed into this bed is very remarkable—sometimes nearly 10 inches.

SECTION XVII.—*Leckhampton Hill.*[1]

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit				5	0
Notgrove Freestone				2	0
Gryphite-grit				5	0
Buckmani-grit.	Sandy limestone	7	8[2]		
	Yellow sand		6		
	Yellowish and purplish marl, with *T. Buckmani* towards the lower part[3]	1	0		
	Yellowish brown limestone	2	6		
				11	8
Lower *Trigonia*-grit.	*Aulacothyris Meriani* 2 feet from the base			7	0
Harford Sands equivalent.	Yellow clayey marl				2
Upper Freestone.	Brownish disintegrated oolitic shale				2
	Freestone.				

The north-easterly route taken is now interrupted by the steep escarpment of Leckhampton Hill, overhanging the valley of the Chelt. At some future time it may be of interest to follow these beds in the same direction on the other side of the valley—across Cleeve Hill up the Northern Cotteswolds. For the present, however, it is necessary to turn aside and take an easterly course; but before doing so the following remarks may be made on the sections given.

It has been by no means difficult to show the continuity of the Lower *Trigonia*-grit[4] from the neighbourhood of Stroud to Leckhampton, wherever any of the intervening beds are present. It has moreover been found persistently at a certain distance below the horizon of *Terebratula Buckmani*. The sections will also have made it clear that beds contemporaneous with the Gryphite-grit of Leckhampton occur in the Stroud neighbourhood, separated by a more or less considerable thickness from the Lower *Trigonia*-grit, and always above the horizon of *Terebratula Buckmani*. It will therefore be evident that to call the Lower *Trigonia*-grit of the Stroud district

[1] A section of the ragstone-beds of this hill was given in my paper on the Bajocian, etc. (Quart. Journ. Geol. Soc. vol. xlix. p. 511), to which the reader is referred. A few details have been added, chiefly of beds ill-exposed at Leckhampton, but better shown on the adjoining Charlton Common, for section of which see p. 412.

[2] It was estimated at about 10 feet for Leckhampton Hill, but this correction is made from exposures in Charlton Common.

[3] The marl and overlying sand have been proved at the Windlass and traced along Charlton Common.

[4] That the Lower *Trigonia*-grit of the Cotteswolds was deposited during the *discitæ* hemera is now well supported by the ammonite-evidence. Wistley Hill (see p. 414), Stroud Hill, the Frith, Rodborough, and Leckhampton have lately yielded to me ammonites indicative of this hemera; and they agree with what Mr. Witchell found at Frith quarry and at Rodborough; while Mr. Upton has obtained confirmatory evidence at the Frith and Stroud Hill. This deposit can therefore be correlated exactly with Dorset. Above this is a considerable thickness of strata—the *T. Buckmani*-grit—which might strictly be considered as deposited during a post-*discitæ* hemera. Above this again is the Gryphite-grit, which contains ammonites of the *fissilobata-ovalis* type and latumbilicate *Witchelliæ*. It can be correlated exactly with Sandford Lane (former paper, p. 492, bed 6 K *c*, and p. 494).

by the name 'Gryphite-grit' is to confuse beds which are by no means contemporaneous; and, further, that if the name 'Lower *Trigonia*-grit' be used at Leckhampton—and it is necessary to employ the term to denote a certain deposit—it is very misleading to lump all the gryphæiferous beds of the Stroud district as 'Gryphite-grit.' This process led to the statement of Lycett, Witchell, and others—that there was in the Stroud district no representative of the Lower *Trigonia*-grit of the Cheltenham district. The sections above given show the contrary.

Reviewing these sections, another curious and rather unexpected fact has been brought to light—namely, the 'Bajocian denudation,' which cut through the 'intervening beds' before the Upper *Trigonia*-grit was laid down. A sloping trough—if I may use the term—some 6 miles broad and nearly 30 feet deep, was cut through these 'intervening beds'; and the lowest part of this trough was close to Cranham Wood, just south of Birdlip. More details may be reserved till after the second part of this paper, which treats of the course eastwards from Leckhampton.

Part II.

From Leckhampton Hill eastwards:

The Discovery in the Cotteswolds of another Ammonitiferous Bajocian Deposit.

More than fifty years ago my father found at Cold Comfort an ammonite which he identified as *Ammonites lævisculus*.[1] When he was Professor at the Royal Agricultural College at Cirencester, he deposited in the Museum, of which he had charge, a considerable portion of his collection for teaching purposes. About the beginning of the troubles which led to the ultimate resignation of the Professorial staff, the then Principal by, apparently, a slightly compulsory purchase, acquired this collection for the College. In this collection was a specimen marked '*Ammonites lævisculus*, Cold Comfort, J.B.,' as I noticed when examining the Museum with Prof. Harker, F.L.S.,[2] a few years ago. This, being a *Witchellia* and not a *Hyperlioceras*,[3] possessed unusual interest for me, because I was then unaware that *Witchellia*-bearing beds existed in the Cotteswolds. Subsequently, with great kindness, Prof. Harker obtained the consent of the present Principal, the Rev. J. B. McClellan, to make me a gift of this specimen, and it is probably the same fossil as that alluded to in the 'Geology of Cheltenham' (p. 27). For this kindness I owe my very best thanks to the

[1] Murchison's 'Geology of Cheltenham,' 2nd ed. 1845, by J. Buckman and H. E. Strickland, p. 27.

[2] Just as this paper is finished, I have unfortunately to say 'the late Prof. Harker,' and to deplore the sad loss of a very kind friend in the prime of life.

[3] Ignorance of the keel-structure may cause some externally-similar species of these genera to be confused. *Hyperlioceras* is well known in the Cotteswolds.

Principal and to Prof. Harker; it has led to an important discovery.

When I wrote my paper on the Bajocian of the Sherborne district,[1] and correlated by other ammonite-evidence the Gryphite-grit with the 'Fossil Bed' of Sandford Lane (a *Witchellia*-bearing deposit), it seemed to me that I had solved the mystery of the occurrence of *Witchellia* in the Cotteswolds. Subsequent examination of Cold Comfort, undertaken by noticing that the matrix of this '*Ammonites læviusculus*' did not correspond to Gryphite-grit, showed me that I had not fully mastered the problem. At Cold Comfort I found *Witchellia*-bearing beds above about 9 feet of Freestone. There was apparently no other clue to the position of these ammonitiferous beds, and they corresponded to nothing with which I was acquainted in the Cotteswolds. It then became necessary to work out their stratigraphical position, and the following is the result.

A walk along the eastern escarpment of Leckhampton Hill (see Section XVII. p. 410) leads to Charlton Common, which is really and actually continuous with Leckhampton Hill, though in a different parish. On the top and on the escarpment of the Common are numerous openings in the 'intervening beds,' affording much better sections than are obtainable on Leckhampton Hill, especially in the *Buckmani*- and Lower *Trigonia*-grits, which are very accessible. The beds are tabulated below :—

Section XVIII.—*Charlton Common.*[2] (Continuous with Leckhampton Hill, overlooking Southfield Farm and Charlton Kings; not marked on the Ordnance 1-inch map.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	Ragstone.				
Notgrove Freestone equivalent.	1. Whitish oolitic limestone, the upper bed much bored.....			4	0
Gryphite-grit.	2. Ragstone-beds, with abundant *Gryphææ*			5	0
Buckmani-grit.	3. Yellow sandy limestones in six beds with sandy partings. '*Terebratula Buckmaniana*' at 6 feet, at 6 feet 7 ins. (broad form), at 7 feet 8 ins. above the sand-bed. *Gryphææ* occasionally in these beds; a bed of them with large wings occurs 3½ to 4 feet above the Sand-bed	7	8		
	4. The Sand-bed. Bright yellow sand and sandy stone		6		

[1] Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 479.

[2] This section is the result of piecing together numerous exposures on the hillside and hilltop. For this work various datum-lines have been used; for instance, the Notgrove Freestone (Bored Bed), the bed of yellow sand, and the subjacent marl with *Terebratula Buckmani*, the hard bed overlying the Lower *Trigonia*-grit, the *Meriani*-bed, and the Upper Freestone.

		ft.	ins.	ft.	ins.
Buckmani-grit.	5. 'The *Buckmani*-marl.' Yellowish and purplish, arenaceous, sticky, shelly marl, with *Terebratula Buckmani* towards the lower part; also *Acanthothyris*, globose species.....	1	0		
	6. Hard, yellow, sandy limestone. The lower bed—'the *Serpula*-bed'—with *S. socialis* (?) abundant, and two or three other species. A few *Gryphæa* also in it	2	6		
				11	8
Lower *Trigonia*-grit.	7. Yellowish, slightly ironshot stone, very crumbly, especially when much exposed; harder and softer layers. Occasional *Gryphæa*. Numerous lamellibranchiata.....	3	5		
	8. Hard band similar to the above, *Pseudomelania*		8		
	9. The *Meriani*-bed. Rather browner, soft marl. *Aulacothyris Meriani* fairly common along this line. *Terebratula* cf. *cortonensis*, *Rhynchonella*, sp.		4		
	10. Stone similar to 8.....		7		
	11. Crumbly, calcareous, earthy marl ...		6		
	12. Earthy, calcareous stone.....		3		
				5	9
Harford Sands equivalent.	13. Yellow, brown, and blue, somewhat sandy clay		8		
	14. Blue, somewhat sandy clay, shell-fragments (*Ostreæ*?).....		10		
				1	6[1]
Upper Freestone.	15. Grey, disintegrated oolitic débris ...				3
	16. Slightly pinkish, somewhat laminated, oolitic stone. Numerous *Ostreæ*, Pectens, and other lamellibranchiata, but all considerably crushed.				
	17. White, oolitic freestone.				

It may be noticed that the Clay-bed at the base of the Lower *Trigonia*-grit is assumed to represent the Harford Sands,[2] and is really first noticeable at the eastern end of Charlton Common, though about 2 inches of it may be seen at Leckhampton Hill (see Section XVII., p. 410). There is a distinct increase in the thickness of the Notgrove Freestone.

About $\frac{3}{4}$ mile farther east is the next section, Wistley Hill. From the details of the section, especially beds 8 and 9, there can be no doubt that this is the section called by Wright and others 'Ravensgate,'[3] a name that I have used in various papers. However,

[1] This was measured at the eastern end of the north flank. About 300 yards to the west only 3 inches of clay was found, overlain by 7 feet of Lower *Trigonia*-grit, *Aulacothyris Meriani* being 2 feet 6 inches up.

[2] 'The Inferior Oolite between Andoversford and Bourton-on-the-Water,' Proc. Cotteswold Nat. Field Club, vol. ix. (1887) p. 108.

[3] 'Subdivisions of the Inferior Oolite,' Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 40.

in the Ordnance Survey-maps it is marked as 'Wistley Hill'; while Ravensgate Hill is the next promontory eastwards. This section is the one overlooking the Vineyards Farm and Charlton Hill, and facing Charlton Common.

SECTION XIX.—*Wistley Hill* (*'Ravensgate'*). (From Cheltenham, 2 miles 7 furlongs S.E. by S.)

		ft.	ins.	ft.	ins.
Buckmani-grit.	1. Yellowish limestone in fair-sized pieces, capping the quarry. *Terebratula Buckmani*, Dav.			1	6
Lower *Trigonia*-grit.	2. Rubbly, yellowish, ironshot ragstone, irregularly mixed with marl, and considerably affected by the weather. *Hyperlioceras*, *Gryphæa*, *Opis cordiformis*, Lycett. Corals	3	6		
	3. Brown marl and marly stone. *Aulacothyris Meriani* and *Rhynchonella*, n. sp.		4		
	4. Yellowish marly stone and marl.....		9		
	5. Brown earthy marl		2		
	6. Yellowish-grey, sometimes pinkish, slightly ironshot, shelly stone.....	1	1		
	7. Soft, yellowish, calcareous, marly stone, very crumbly		6		
				6	4
Representative of Harford Sands.	8. Yellowish-brown and bluish, somewhat argillaceous sand	1	0		
	9. Brownish, bluish, and greyish arenaceous clay with shell-fragments (*Ostrea?*)	1	7		
				2	7
Upper Freestone.	10. Whitish oolitic debris				3
	11. Stone, presumably 'Upper Freestone.'				

Note.—Part of Bed 6, and all of the other beds, are covered by fallen quarry-rubble. It was necessary to excavate through this, so that only a temporary and indifferent exposure was obtained.

My thanks are due to Mr. Charles Upton for ascertaining the exact horizon of *Aulacothyris Meriani*, which I have subsequently confirmed.[1] It may be that it also comes in the bed higher up; but it is to be met with for a certainty along the line given. The specimen of *Hyperlioceras* discovered is somewhat poor; it is nearest to the example of *H. discoideum* figured in my monograph, pl. xix. figs. 3, 4,[2] but more compressed round the umbilicus.

It should be noted that the *Buckmani*-grit is incomplete here, on account of subaerial erosion.

About ½ mile south-east of Wistley Hill is Chatcombe[3] Pitch. There is a small section on the top of the Pitch, south side, by the

[1] This knowledge enabled me to trace its horizon in the other sections, and to find it readily.

[2] 'Monogr. Inf. Oolite Ammonites,' pt. iii., Pal. Soc. vol. xlii. 1889.

[3] The Ordnance Survey 1-inch map has (incorrectly) 'Chalcomb.' This is corrected on the 6-inch map.

edge of the Wood; and on the north side are openings, of rather incomplete nature, in the Oolite Marl and Lower *Trigonia*-grit. By the use of the level the following results were obtained:—

SECTION XX.—*Section at Chatcombe Pitch.* (From Cheltenham, $3\frac{1}{4}$ miles S.E. by S.)

		ft.	ins.	ft.	ins.
Notgrove Freestone.	1. Grey, oolitic limestone irregularly mixed with earth, disturbed owing to proximity to the surface	3	0		
	2. Limestone in fairly compact beds. Shelly layer—sundry broken shells —in lower part	2	0		
				5	0
Gryphite-grit.	3. Ragstone, with numerous *Gryphæa* visible	1	6		
Buckmani-grit (hidden).	4. From the top of the Gryphite-grit to the exposure of Lower *Trigonia*-grit on the other side of the road, down the hill, taken by a level, is 17 feet	15	6		
Lower *Trigonia*-grit.				17	0
Upper Freestone (hidden).	5. From this exposure of Lower *Trigonia*-grit to an exposure of Oolite Marl with *Terebratula fimbria*, *Rhynchonella subobsoleta*, etc., lower down the road	.....		21	0
Oolite Marl.					

This section does not quite join that of Wistley Hill, for there remains unknown the thickness of the Gryphite-grit and of the *Buckmani*-grit, only portions of these series being exposed in the respective sections. The thickness of the two combined may be known approximatively, as the distance from the top of the Gryphite-grit to the Lower *Trigonia*-grit is 17 feet. Therefore, somewhat the following may be taken as the generalized section of Wistley Hill and Chatcombe Pitch:—

	ft.	ins.
Notgrove Freestone (partly denuded)	5	0
Gryphite-grit	5	0
Buckmani-grit	10	0
Lower *Trigonia*-grit } as at	6	4
Harford Sands } Wistley Hill	2	7
Upper Freestone	14	0

About 3 furlongs north-east is a section at Ravensgate Hill, on the eastern flank thereof, just outside Lineover Wood. It is practically a repetition of Wistley Hill, but shows a greater thickness of Lower *Trigonia*-grit.

SECTION XXI.—*Ravensgate Hill.* (From Cheltenham, 3 miles 2 furlongs S.E.; from Leckhampton Hill, 2 miles 2 furlongs E., just outside Lineover Wood.)

		ft.	ins.	ft.	ins.
Buckmani-grit.	1. Grey sandrock, weathering yellow, *Terebratula Buckmani*, *Gryphæa*, *Serpulæ*, to top of quarry			2	0

		ft.	ins.	ft.	ins.
Lower *Trigonia*-grit.	2. Marl and Stone	1	6		
	3. Ironshot ragstone	4	6		
	4. Marly stone, sometimes marl with *Aulacothyris Meriani*		4		
	5. Yellow marl with *Aulacothyris Meriani*		3		
	6. Grey oolitic ragstone	1	8		
	7. Marly stone	1	2		
				9	5
Representative of Harford Sands.	8. Blue clay		5		
	9. Yellow clay		2		
					7
Upper Freestone.	10. Pink oolitic limestone			1	0
	11. White oolitic limestone			12	0

From the top of the Upper Freestone to an exposure, of what is with fairly good reason considered to be Upper *Trigonia*-grit, higher up the hill is 39 feet. Deducting herefrom the Lower *Trigonia*-grit and Harford Sands (10 feet), and then the amount ascertained for the Gryphite- and *Buckmani*-grits at Chatcombe Pitch (15 feet), leaves 14 feet of strata separating the Gryphite- and Upper *Trigonia*-grits. The last complete data obtained—at Charlton Common (p. 412)—gave 4 feet of Notgrove Oolite in this position. There is a considerable expansion here of Notgrove Oolite, and, as will be seen later, presumably of something more.

About 3 furlongs eastward is an old disused quarry by the roadside. After some trouble in clearing away débris, its somewhat compact mural face afforded the following section:—

Section XXII.—*Near Lineover Wood.* (Above and to the south of the wood, on the left-hand side of the high road from Gloucester to Oxford; near the 11th milestone from the former place. From Cheltenham, $3\frac{1}{2}$ miles S.E.; from Leckhampton Hill, 2 miles 5 furlongs E.)

		ft.	ins.	ft.	ins.
Upper *Trigonia*-grit.	1. Hard, grey, shelly ragstone with numerous *Trigoniæ* (impressions) and brachiopoda of the Upper *Trigonia*-grit			2	0
Witchellia-grit.	2. Yellow, slightly ironstained ragstone. Gasteropoda in sections, *Serpulæ*, *Avicula*		11		
	3. Grey, shelly, oolitic stone, somewhat ironstained, small *Acanthothyris* cf. *paucispina*. Top layer considerably bored		10		
	4. Greyish-brown, very shelly stone. (This and the bed above are somewhat laminated.)		4		
	5. Yellow mud		1		
	6. Greyish-brown, shelly ragstone. *Astarte elegans*, *Modiola*, dwarf *Gryphæa*	1	8		
				3	10
Notgrove Freestone.	7. White, very oolitic stone, like freestone.				

In this section there are nearly 4 feet below the Upper *Trigonia*-grit, which are not Notgrove Freestone; but Bed 7 seems to be that rock. Apparently then, combining this with Ravensgate Hill, it would be right to put the Notgrove Freestone at 14—4 feet, that is, 10 feet; and above it some beds, certainly not Upper *Trigonia*-grit, which have not been found at any other section.

What these beds are is explained in the next section—about 500 yards eastward—namely, that of Cold Comfort. It shows, above about 9 feet of freestone (the Notgrove Freestone), 4 feet of ragstone-beds corresponding to those of Lineover, and containing Sonninим, mostly angustumbilicate *Witchellicæ*. The upper 4 feet I propose to call *Witchellia*-grit. At this section the *Witchellia*-grit is not capped by the Upper *Trigonia*-grit; but that is evidently very close at hand, for some of its fossils are occasionally mixed in the disturbed part at the top. Also, compared with Lineover, which shows 3 feet 10 inches in this position, it would be expected to follow directly on the top of Bed 1. The following is the section :—

Section XXIII.—*Cold Comfort.* (From Cheltenham, 3¾ miles S.E.; from Leckhampton, 3 miles E. The quarry is about 3 furlongs west of Cold Comfort Cottages, on the right-hand side of the road to Gloucester.)

		ft.	ins.
Witchellia-grit.	1. Grey, shelly, sandy stone, not ironshot; *Acanthothyris* cf. *paucispina*, small forms rather common, but often only single valves; larger specimens scarce. *Pseudomelania* (?) cast, *Bourguetia* (?) cast. Small elongate *Terebratula*. Thickness about	1	0
	2. Similar stone; but no fossils were noticed ...	1	0
	3. Greyish, rather ironshot, shelly stone. Various species of *Witchellia*, and *Terebratula Wrighti*		5
	4. Greyish, fairly ironshot, shelly stone. The iron grains are rather angular in shape; they fall out and leave the stone pitted. Flattish *Terebratula*. Small smooth *Pecten* rather common		6
	5. Somewhat cream-coloured, shelly stone, broken up and mixed with rubbly marl. Weathered pieces show polyzoa	1	1
Notgrove Freestone.	6. Whitish limestone, with a more or less pink tinge and iron-stains, considerably bored, in places more than 1 foot vertically; *Ostreæ* and *Gryphææ* occasionally, although the rock is generally unfossiliferous	2	3
	7. Whitish limestone, 'Freestone,' with small whitish oolite-grains; visible	7	0
Gryphite- and *Buckmani*-grits hidden.	8. From the top of the Notgrove Freestone to the base of the Lower *Trigonia*-grit,[1] shown resting on the top of the Upper Freestone		

[1] Another old quarry, on the slope of the hill to the north, showed Lower *Trigonia*-grit 104 feet below this quarry; but that is evidently a slipped portion.

		ft.	ins.
Lower *Trigonia*-grit.	in a disused quarry just west of Cold Comfort Cottages, on the right-hand side of the road from Gloucester to Oxford, is 30 feet.[1] Therefore 30—9 gives.....	21	0
Upper Freestone.	9. From the top of the Upper Freestone to an exposure of Oolite Marl on the left-hand side of the road, just east of Cold Comfort Cottages is 18 feet. Immediately W. of the cottages, on the same side and in the same field as the top quarry, is an Upper Freestone quarry about 15 feet deep.....	18	0
Oolite Marl.	10. Marl with *Terebratula fimbria* and characteristic fossils.		

I am indebted to my friend Mr. Charles Upton, who made an independent section of the quarry, for calling my attention to certain details here given. He has also collected *Terebratula Wrighti* and *Witchelliæ* from here, and gives them the same position. I have, moreover, a small spinous *Sonninia* aff. *Sowerbyi*, found loose, in a matrix agreeing with Bed 5.

The beds above the Notgrove Freestone (6) are more or less broken up and disturbed. They are mixed with more or less earthy marl, and it is in this that *Terebratula Wrighti* is found. Its general level is from $1\frac{3}{4}$ to 2 feet above Bed 6; but one specimen has been found 8 inches above that bed. Of the beds above 6 there are only 3 feet shown directly in the section; but by working farther east a higher horizon, the one with *Acanthothyris*, is found. Owing to the disturbed nature of the upper beds it was not possible to ascertain the exact thickness of this *Acanthothyris*-bed; but it was estimated at not less than 1 foot. This is the same *Acanthothyris* as that which is found in the section at Lineover, by the roadside; and, therefore, though no *Witchellia* and no specimens of *Terebratula Wrighti* were found there, this little fossil is to a certain extent palæontological evidence of the identity of the ragstones which at Cold Comfort and at Lineover lie above the Notgrove Freestone. These ragstones are not Upper *Trigonia*-grit: that is proved at Cold Comfort by the ammonites—*Witchelliæ* are indicative of a deposit which was laid down 4 hemeræ before that of the Upper *Trigonia*-grit (*Garantianæ* hemera).[2] At Lineover these ragstones are capped with Upper *Trigonia*-grit; at Cold Comfort the same bed must have lain almost immediately over the *Witchellia*-grit, though it could not be found in that position. There are, however, brachiopoda of the Upper *Trigonia*-grit to be found on the spoil-heaps, and blocks with the same fossils: these have probably been left among the thin soil which capped the quarry, and some of them may be wedged among the top beds.

The *Witchellia*-grit has been, in part, noticed by Wright as the *Perna*-bed; my reason for calling it by its present name is that this

[1] The above measurement (30 feet) must be considered approximative, the quarry being much inclined.

[2] 'The Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 493 and Table II.

appellation suggests contemporaneous strata in Dorset and on the Continent, known as *Witchellia*-beds. Concerning the *Perna*-bed Wright says, 'It is probable likewise that the *Perna*-bed may represent a higher portion of the Upper *Trigonia*-grit than that exposed at Leckhampton Hill'; and he gives it a thickness of 6 inches, below 4 feet of ragstone.[1] Dr. Wright discovered *Terebratula Wrighti* in it,[2] and he also quotes *Ammonites Edouardianus* therefrom.[3] The same specimen as that here referred to is, probably, the one in my cabinet now, purchased from his collection. It is not *Edouardianus*, though closely resembling it. It is a somewhat latumbilicate *Witchellia*, allied to *Witchellia Sutneri* (Branco).

Wright's location of the '*Perna*-bed,' as probably above the Upper *Trigonia*-grit, was a mistake. The ammonites alone show this—not only that it is really below the Upper *Trigonia*-grit, but that a very considerable amount of time elapsed after the deposition of the *Perna*-bed (*Witchellia*-grit) and before the Upper *Trigonia*-grit was laid down; while during this time strata were being laid down in other localities.[4] But, independently of any ammonites, the *Perna*-bed (*Witchellia*-grit) is actually below the Upper *Trigonia*-grit by stratigraphical evidence. Again, it caps a freestone, and the highest bed of this kind at present known in what is called 'Inferior Oolite' is the Notgrove Freestone. Further, the stratigraphical position of this bed is shown by the sections described in the present paper.

The *Witchellia*-grit has been probably alluded to by my father in the section of Lineover in the 'Geology of Cheltenham.' On p. 25 he notices a bed of argillaceous stone (No. 3) between the *Trigonia*- and Gryphite-grits, from which he quotes a considerable series of species (p. 27). The *Ammonites lævisculus* which he mentions is very probably the specimen now in my cabinet—alluded to on p. 411. My father was right in the position he assigned to this bed, though it is only part of what I place as *Witchellia*-grit.

Part I. of this paper has shown that between Stroud and Leckhampton the highest bed upon which the Upper *Trigonia*-grit rests is the Notgrove Freestone. Comparison with Dorset has proved that even then strata deposited during certain hemeræ are unrepresented, so that the Upper *Trigonia*-grit rests non-sequentially on the Notgrove Freestone. The discovery of about 4 feet of grits capping the Notgrove Freestone, and yielding ammonites (angustumbilicate *Witchelliæ*) is interesting in many respects; it slightly lessens the gap between the Upper *Trigonia*-grit and subjacent beds; it is noteworthy as an ammonitiferous deposit in a district where ammonites of the post-*opalini* hemeræ are rare; it confirms in a satisfactory manner a surmise made in respect to the chronology of Dorset strata. Thus, in correlating certain Dorset and Gloucestershire strata in my previous paper (pp. 509–514), I stated

[1] 'Subdivisions of the Inferior Oolite,' Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 42.

[2] Davidson, 'Jurassic Brachiopoda,' App. to vol. i. p. 20, Pal. Soc. 1854.

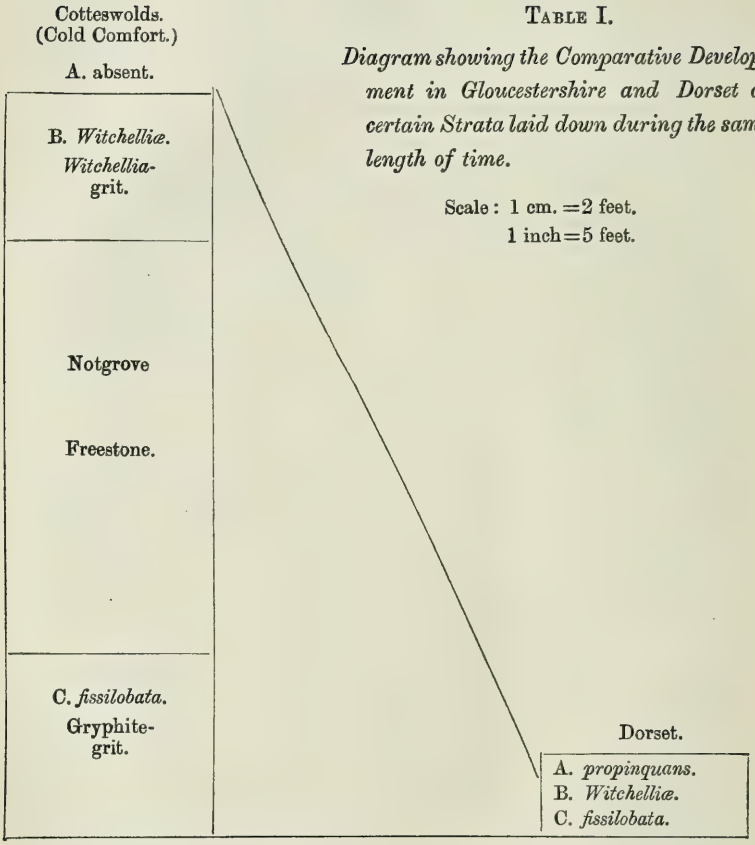
[3] *Op. jam cit.* p. 43.

[4] Compare Table II., p. 422, and see Postscript, p. 461.

Table I.

Diagram showing the Comparative Development in Gloucestershire and Dorset of certain Strata laid down during the same length of time.

Scale: 1 cm. = 2 feet.
1 inch = 5 feet.



that the 'Notgrove Freestone equivalent' and the 'Gryphite-grit' had been deposited during the *Witchelliæ* hemera, contemporaneously with the lower part of the Sandford Lane 'Fossil Bed.' Further, I stated on p. 495 in regard to that particular 'Fossil Bed':—'My own impression is that if the strata were more developed, it would be seen that the species which lived during three hemeræ are contained in the 'Fossil Bed' of Sandford Lane, (*a*) species of the *Sonninia propinquans*-type; (*b*) *Witchellia* and allies; (*c*) species of the '*Sonninia*' *fissilobata* type.' This recent work in the Cotteswolds, where the strata are so very much thicker than in Dorset, has shown that such a surmise can be fully substantiated. The bed now called *Witchellia*-grit, because it yields angust-umbilicate *Witchelliæ*, lies several feet above the Gryphite-grit which contains the *fissilobata*-type of ammonite. The comparative diagram on the opposite page (Table I.), showing the relative development of strata in Gloucestershire and in Dorset, will explain how that which, on account of thinness of strata, could only be surmised in the latter county, can be fully proved in the former, where the deposits are so much thicker.

In my former paper the middle and lower parts of the Sandford Lane fossil-bed were considered to have been deposited during what was called a *Witchelliæ* hemera, contemporaneously with the Gryphite-grit of Leckhampton. Now greater precision can be attained. The middle part of the Sandford Lane fossil-bed was deposited contemporaneously with the *Witchellia*-grit at Cold Comfort; the lower part was deposited contemporaneously with the Gryphite-grit of Leckhampton: between the two Cotteswold beds lies the Notgrove Freestone. Therefore it is necessary to call the time during which the upper deposits were laid down '*Witchelliæ* hemera,' and to the time during which the lower beds were accumulated it will be advisable to give a new name, say, '*Sonniniæ* hemera.' Consequently, one will need to remember that the space of time called *Witchelliæ* hemera in my former paper is now divided into *Witchelliæ* hemera preceded by *Sonniniæ* hemera—but the correlation of the deposits themselves remains practically the same. The placing of the Notgrove Freestone in the later hemera is a mere matter of convenience; it ought to be divided between them.

Table II. (see next page) will illustrate the correlation of the Gloucestershire and Dorset strata according to the method described above. It shows that from the *discitæ* to the *Witchelliæ* hemeræ (inclusive) there was deposited in the Cotteswolds about 38 feet[1] of strata, and in the Sherborne district only about 3 feet. The correspondence in the faunal succession is remarkable, and the greater accumulation of deposit in the Cotteswolds justifies the statement that the acme of the *Witchelliæ* was very distinctly later than the time when the ammonites of the *fissilobata-ovalis* type were in existence.

[1] If the *Witchellia*-grit had capped the Notgrove Freestone at Chedworth Wood there would have been about 60 feet of strata (see *infra*, p. 425).

TABLE II.—CORRELATION OF GLOUCESTERSHIRE AND DORSET STRATA.

Hemeræ.	Leckhampton, Cold Comfort, etc.	Sandford Lane and Frogden (Sherborne).
Garantianæ.	Upper *Trigonia*-grit. 5 feet.	Building-stone with *Parkinsoniæ.* 25 feet.
Niortensis.	Absent from Leckhampton and not present, to my knowledge, in the Cotteswolds.	Absent from Sandford Lane. Ironshot Oolite with *Ancyloceras*, *Parkinsoniæ*, etc. 3 feet.
Humphriesiani.		Ironshot Oolite with *Stephanocerata.* 2 feet.
Sauzei.		Limestone with '*Stephanoceras*' *Sauzei* and *Sonniniæ* of the *propinquans* type.
Witchelliæ sp.	*Witchellia*-grit, with angustumbilicate *Witchelliæ*. Only near Cold Comfort. Absent from Leckhampton. 4 feet.	Limestone with angustumbilicate *Witchelliæ* and *Sonniniæ* of the *fissilobata*-type, the latter mostly at the bottom of the bed. About $1\frac{1}{2}$ feet.
	Notgrove Freestone. 10–30 feet.	
Sonniniæ sp.	Gryphite-grit, with *Sonniniæ* of the *fissilobata-ovalis* type. About 5 feet.	Sandy limestone with *Sonninia ovalis.* A few inches.
Post-*discitæ* and *Discitæ.*	Sandy limestone, with *Terebratula Buckmani.* About 12 feet.	Sandy parting and some stone with *Terebratula cortonensis* and *Hyperliocerata*, the former at the top. About $\frac{3}{4}$ foot.
	Lower *Trigonia*-grit, with *Hyperliocerata.* About 7 feet.	
Concavi.	No actual evidence; but the Harford Sands occupy the same stratigraphical position.	Sandy stone with *Lioceras v-scriptum* and allies. 3 feet.

A detailed comparison with Dundry would be even more striking, but that I do not feel justified in giving. Mr. E. Wilson, F.G.S., and myself have made many investigations at Dundry Hill; we are, however, unable just yet to prepare our results for publication. I write, nevertheless, with a knowledge of those results.

It is advisable to add two more sections to this part of the paper, whereof the first is noticeable because the *Witchellia*-grit is denuded, though the section itself is close to that just given (p. 417), and because it yields more satisfactory measurements of the other 'intervening beds.' The other section is remarkable for the great thickness of the Notgrove Freestone.

About $\frac{3}{4}$ mile S.S.E. of the Cold-Comfort exposure is a quarry by the side of the road leading to Hilcot; and by following the lane down to Pinchley Grove it is possible to obtain an approximative section from casual outcrops, so as to connect the beds of this quarry with strata which are well exposed in Pinchley Grove itself. It is advisable to give the results obtained here, because they check the thicknesses given at Cold Comfort for the beds above the Oolite Marl; in fact, the results are more trustworthy than those noted for Cold Comfort.

SECTION XXIV.—*Rough Hill Bank* (*Pegglesworth Hill*).[1]
(From Leckhampton Hill $3\frac{1}{4}$ miles E. by S.)

		ft.	ins.
Upper *Trigonia*-grit.	1. Shelly ragstone with earthy partings. *Terebratula globata*, *Rhynchonella hampenensis*.[2] *Parkinsonia* latumbilicate sp., half-whorl of body-chamber of a specimen 13 inches across, 2 feet 10 inches above the Bored Bed. Hard grey, very shelly ragstone, with *Trigoniæ*, *Rhynchonella* cf. *subtetrahedra*, *Terebratula* cf. *globata* (crushed), immediately overlying the Bored Bed. Total thickness to top of quarry	4	0
Notgrove Freestone.	2. 'The Bored Bed.' Hard, bluish-grey limestone, very much bored by annelids. Oysters on top of it		5
	Along road to Hilcot:—		
	3. Cream-coloured, very oolitic freestone, about 2 feet visible in quarry. Exposed along road to Hilcot about 146 yards, dropping 22 feet. Deducting dip of 1°, this makes thickness ...	13	0
Gryphite-grit.	4. Ragstone with *Gryphæa* obscurely exposed in the lane for about 60 yards, dropping 10 feet. Deducting 4 feet for dip gives	6	0
Buckmani-grit.	5. Sandy beds, exposed at intervals along the lane; a broad *Terebratula* aff. *Buckmaniana* found. Distance about 93 yards, dropping 18 feet; deducting 6 feet for dip of 1° gives	12	0

[1] These names are not given on the 1-inch map. On that the farm is called Foxcote Hill Farm, while on the 6-inch map it is called Pegglesworth Hill. The quarry is on the left-hand side of the road leading to Hilcot, and the road thence into Pinchley Grove affords more or less of a section, and in the latter place a very fair one.

[2] *Rhynchonella subtetrahedra* and *Zeilleria Hughesi* on spoil-heap.

	Lane in Pinchley Grove :—	ft.	ins.
Lower *Trigonia*-grit.	6. Ironshot limestone exposed for 29 yards, dropping 6 feet; deduction for dip 1½ feet gives ..... (*Aulacothyris Meriani* 8 inches from the bottom of this bed.)	4	6
Upper Freestone.	7. Oolitic Freestone, the top bed pinkish, others whitish or cream-coloured, exposed for about 80 yards, dropping 22 feet; 5½ feet deduction for dip gives	16	6
Oolite Marl.	8. White marly stone, *Rhynchonella Tatei*, small *Rh.* sp., *Terebratula fimbria*, *Nerinæa*, about...	1	0
	9. Whitish earthy stone, considerably mixed with marl. *Terebratula fimbria*, common; *Lioceras* cf. *bradfordense*, fragment; and *Rhynchonella subobsoleta* at about 1 foot 6 inches from bottom of bed. Total thickness	2	0
	10. Similar, perhaps rather more marly; *Terebratula curvifrons*, common; *T. submaxillata*.	1	8
	11. Soft, white, chalky marl; *Rhynchonella* sp. in top part; one specimen of *Zeilleria Leckenbyi* at the bottom		10
Lower Freestone.	12. Cream-coloured oolitic freestone.		

It will be noticed that the Upper *Trigonia*-grit directly overlies the Notgrove Oolite, so that the *Witchellia*-grit is absent: it has been denuded altogether before the Upper *Trigonia*-grit was laid down. This defines the geographical extension of the *Witchellia*-grit in a southerly direction (see *infra*, p. 437).

The thickness of the Notgrove Freestone works out at 13 feet 5 inches. This accords very fairly with the figure obtained for Ravensgate. The Gryphite-grit and the *Buckmani*-grit are very obscurely seen in the lane; it is, therefore, quite possible that a foot or so too much may have been given to the former at the expense of the latter.

It is interesting to carry this examination somewhat further, and to compare with the results obtained a section on the new line between Andoversford and Cirencester. I have already described the sections of this line[1] and of the line from Andoversford to Bourton-on-the-Water,[2] on both of which the Notgrove Freestone is much in evidence, but the *Witchellia*-grit is absent. All the sections of these railways might, however, be profitably examined once more in the light of experience gained in the district attacked by the present paper, not with any great hope of finding the *Witchellia*-grit, but with the view of bringing the details into accordance with those now given. Thus the following section has been amended, and differs somewhat from what it was in my above-quoted paper. The former section was made while the cutting was incomplete, when the beds presented a much different and far more compact appearance, before the frost had lent its aid in giving an additional factor of distinction—degree of liability to shatter and crumble.

The following, therefore, is the section recently made:—

[1] Proc. Cottesw. Nat. Field-Club, vol. x. (1890) p. 94.
[2] *Ibid.* vol. ix. (1887) p. 108.

Section XXV.—*Chedworth Wood.* (Cutting on the Railway to Cirencester. From Leckhampton, $6\frac{3}{4}$ miles E.S.E.; from Cheltenham, $8\frac{1}{2}$ miles S.E.)

		ft.	ins.	ft.	ins.
Notgrove Freestone.	1. White oolitic Freestone similar in texture to the Upper and Lower Freestone. Abdomen of a large ammonite, a slightly carinate form, presumably *Sonninia*, 4 feet 6 inches from the base			30	0
Gryphite-grit.	2. Greyish, somewhat marly stone, with the *Gryphææ* very abundant .			4	0
Buckmani-grit.	3. Grey sand-rock in several beds, with occasional *Gryphææ*, the upper bed 1 foot 4 inches thick, rather barren, but very considerably bored, with even top—a noticeable datum-line in the cutting	3	8		
	4. Greyish, weathering light yellow, very sandy rock. Numerous shells in section. *Gryphææ* in upper part: abdomen of a large ammonite showing 3 feet up	3	2		
	5. Pinkish and bluish-grey clayey marl; only 1 small *Terebratula Buckmani*, juv.?, found. Belemnites, scarce...		8		
	6. Yellowish-brown, sandy stone.....		10		
	7. Brown, earthy parting.....		1		
	8. Bluish-grey, sandy stone		3		
	9. Earthy parting.....		1		
	10. Hard, grey, sandy stone with *Serpulæ*. *Sonninia* found just below this horizon—not *in situ*—may belong here.....	1	4		
				10	1
Lower *Trigonia*-grit.	11. Ironshot marl and stone, rather crumbly: *Ostrea* cf. *explanata*, *Trigonia*, *Myacites*, etc.		11		
	12. Pinkish stone: *Myacites*, *Cypricardia cordiformis* (?), *Cucullæa*	1	2		
	13. Yellowish stone.....	1	3		
	14. Marly parting more or less conspicuous: *Aulacothyris Meriani*		2		
	15. Yellowish, slightly ironshot stone ...	1	5		
	16. Yellowish, oolitic marl and some stone		5		
				5	4
Harford Sands equivalent.	17. Bluish and yellowish clay with numerous fragments of shells: *Ostreæ*.....				6
Upper Freestone.	18. Yellowish and bluish oolitic limestone.				

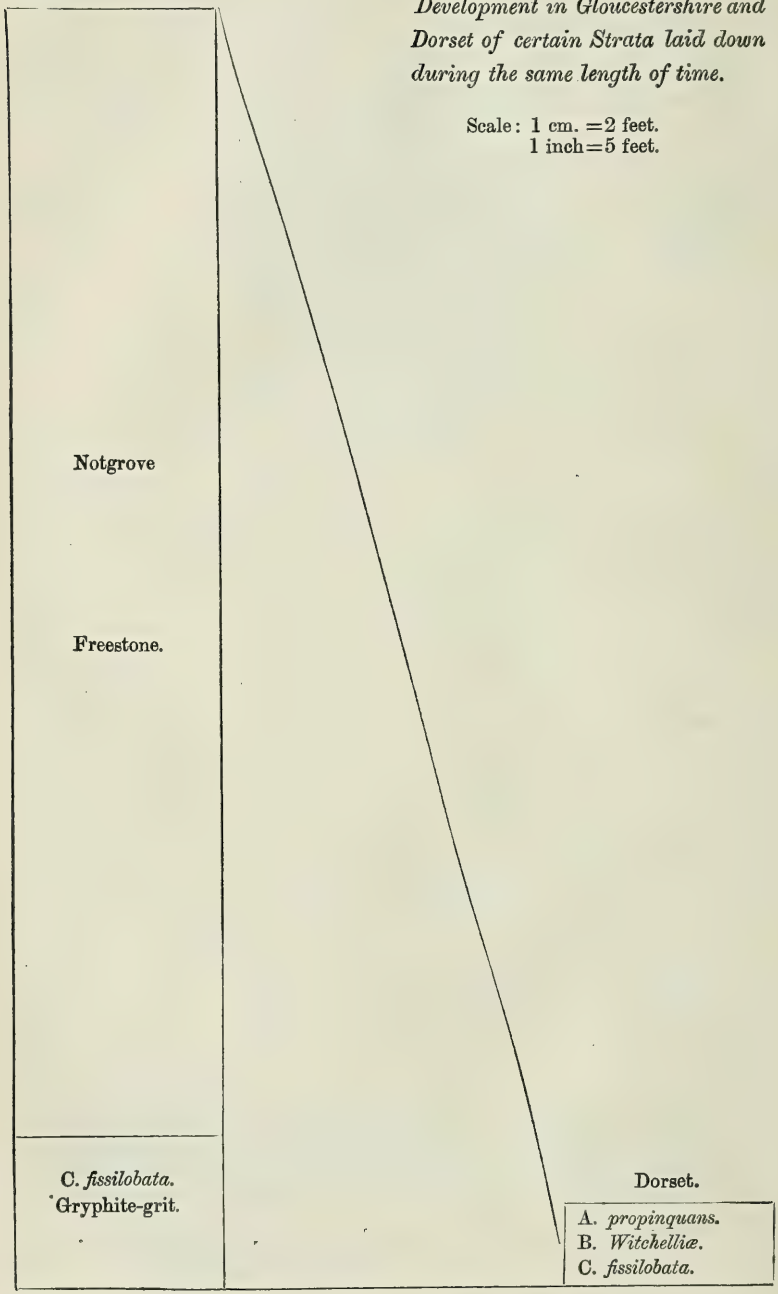
With regard to this section I may remark that in my paper read to the Cotteswold Nat. Field-Club, although I correlated Beds 12–17 as Lower *Trigonia*-grit, I also stated that Bed 18 might be part of it. Herein Mr. H. B. Woodward[1] has very rightly corrected me—it is certainly Upper Freestone. Also in that paper I overlooked

[1] 'Lower Oolitic Rocks of England,' Mem. Geol. Surv. 1894, p. 127.

Table III.

Diagram showing the Comparative Development in Gloucestershire and Dorset of certain Strata laid down during the same length of time.

Scale: 1 cm. =2 feet.
1 inch=5 feet.



the significance of Bed 17, which Mr. Woodward has rightly appreciated. I had come to the same conclusion during the work for this paper at Wistley Hill and Ravensgate before his book was published; but such a clay-bed had not come to my notice when I described the railway. Bed 17 is obviously contemporaneous with the Harford Sands, which are so much more important to the north and north-east.

As to the strata now called *Buckmani*-grit, they were parted between the Gryphite-grit and the Lower *Trigonia*-grit, the need of a distinct term not having been recognized. The Gryphite-grit was credited with the larger share, and so its thickness was made rather considerable. It is not possible, under the present system of treatment, to regard more than 4 feet as having been deposited contemporaneously with the true Gryphite-grit bed of Leckhampton, that of necessity being taken as the typical locality for reference.

Above the Gryphite-grit there is a very remarkable thickness of the Notgrove Freestone. It is now put at a greater thickness than before, based on the estimate of a workman, with which I saw no reason to disagree. All this thickness is shown in the one cutting, but even then this deposit is incomplete, for there is no Upper *Trigonia*-grit—that has been removed by Quaternary denudation. Other cuttings show the Upper *Trigonia*-grit resting on the Notgrove Freestone; but they give no clue to the thickness of the Freestone. All that can be said is that about 30 feet of Notgrove Freestone is shown in one cutting; that then the deposit is incomplete; that the thickness may be considerably greater; but 30 feet is a safe minimum.

There is no reason to doubt that the *Witchellia*-grit once capped the Notgrove Freestone here shown, but it has been removed by Bajocian denudation. Such being the case, it is very instructive to notice the great thickness which would have separated the *Witchellia*-grit from the Gryphite-grit, and then to compare that with the Sandford Lane 'Fossil Bed,' as in the diagram (Table III.) on the opposite page. Therefrom it will be understood how no difficulty could arise in appreciating in the Cotteswolds an ammonite-sequence which in Dorset the paucity of sediment obscured, though that seems a paradox.

Analysis of Sections.

A tabular statement of the results obtained by an analysis of all the sections may now be advantageously given. In the first place, a straight line from Mount Surat N.E. by N. to Leckhampton has been taken; and the thicknesses of the various deposits in the different quarries are given in Table IV. (p. 428), with notes where required. These thicknesses have been plotted to scale in the diagram, Table VI. (facing p. 430), by the same method as in my former paper; that is, localities off the line have been placed at the distances where they fall at right angles to it. From Leckhampton Hill a second line has been drawn at an obtuse angle to the first, to Cold Comfort due east; and at the side of the Table, for com-

TABLE IV.—*Analysis of Sections, No. 1: Mount Surat to Leckhampton, N.E. by N.*

	Mount Surat.	Rodborough.	Stroud Hill.	Swifts Hill.	Frith.	Bull Cross.	Sheepscombe.	Dunley.	Cranham Wood (Buckholt).	Buckle Wood.	Birdlip.	Cuckoo Pen.	Tuffley's.	Leckhampton.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Witchellia-grit					Incomplete.									
Notgrove Freestone	...	...	1 2	1 4		Incomplete.	...	...	...	...	...	...	...	2 0
Gryphite-grit	...	...	5 9[3]	7 0			3 3	...	...	...	...	...	...	5 0
Buckmani-grit	...	1 5[2]	4 4[4] / 5 10	7 3	8 6		Not exposed.	2 2[5]	...	...	...	...	5 11	11 8
Lower *Trigonia*-grit	1½[1]	1 11	2 9	5 4	3 6	4 0		Not exposed.	...	...	...	3 2[6]	3 0	7 0
Harford Sands	...	...	...	...	...	...			...	...	...	...	...	2

[1] There is no definite palæontological evidence to warrant placing this as Lower *Trigonia*-grit. It is merely a parting between the Upper *Trigonia*-grit and the Upper Freestone, and for practical purposes may be disregarded.

[2] Some of this bed may belong to the Lower *Trigonia*-grit, but the finding of *Terebratulæ* of the *Buckmani*-type indicates the presence of a certain deposit of *Buckmani*-grit at Rodborough.

[3] In lithological character these beds do not agree with the Notgrove Freestone. Though destitute of *Gryphææ*, they may be contemporaneous with the Gryphite-grit proper of Leckhampton (see p. 397).

[4] This thickness is probably too small; between the bottom bed of the workhouse quarry and the top one of the Coneygre quarry there may be some beds wanting (see p. 396).

[5] Correlation with the section in Buckholt (Cranham) Wood suggests a thickness of 8 or 9 feet.

[6] A few inches may belong to the *Buckmani*-grit.

TABLE V.—*Analysis of Sections, No. 2: Kimsbury Castle to Cold Comfort, E.N.E.*

	Selsley.	Randwick.	Scotesquar & Bird-in-Hand.	Kimsbury Castle.	Buckholt (Cranham) Wood.	Dunley.	Cranham (Buckholt) Wood.	Buckle Wood.	Birdlip.	Cuckoo Pen.	Tuffley's.	Leckhampton.	Charlton Common.	Wistley Hill.	Chatcombe Pitch.	Ravensgate Hill.	Lineover.	Cold Comfort.	Hilcot Lane.	Chedworth Wood (Railway-cutting).
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		ft. in.	ft. in.	ft. in.
Witchellia-grit	...	.....	...	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	3 10	4 0		
Notgrove Freestone ...	...	.....	...	4 0	.....	.....	...	...	...	...	...	2 0	4 0	...	5 0[3]	39 0[4]	Not exposed.[5]	9 35	13 0	30 0
Gryphite-grit	...	8 0[1]	4 0	5 6	3 2	.....	...	...	...	...	...	5 0	5 0	...	15 0			30 0	6 0	4 0
Buckmani-grit	...		6 0	17 5	11 4	2 2[3]	..	...	...	...	5 11	11 8[2]	11 8[2]	1 6[3]		2 0[3]			12 0	10
Lower *Trigonia*-grit ...	...	7	5 6	1 0[6]	Incomplete exposure.[7]	Incomplete exposure.	...	...	...	3 2	3 0	7 0	5 9	6 4	8 11	9 5			4 6	5 4
Harford Sands	...	.....	...	.....			...	...	...	...	...	2	1 6	2 7		7		.....	.....	[6]

[1] Somewhat incomplete; an estimate.

[2] These beds are not fully exposed on Leckhampton Hill, but the thickness has been ascertained from piecing together various sections on the contiguous and continuous Charlton Common, and the same thickness has been taken for Leckhampton Hill.

[3] Incomplete.

[4] Beds not fully exposed. Thickness ascertained by level.

[5] Not exposed further. From top of Notgrove Freestone to base of Lower *Trigonia*-grit, shown in an old quarry lower down the hill, is 30 feet by the level; but the beds in the top quarry have a high dip, and the thickness is only approximate.

[6] The disturbed condition of the beds renders this measurement and the position of the *Terebratula Buckmani*-marl a little uncertain. What is given shows actual results obtained.

[7] There are 2 feet 6 inches or more to the bottom of the quarry, possibly belonging to the Lower *Trigonia*-grit.

parison, is shown the development of beds at Chedworth Wood (in the railway-cutting), though this place lies away to the south-east and is not here in true position. The interesting points, however, at this locality are the noting of the *Meriani*- and *Buckmani*-horizons, and the great thickness of the Notgrove Freestone.

The thicknesses are given in another Table (V. p. 429), in reference to another line of country—from Kimsbury Castle to Cold Comfort, E.N.E.; but the localities from Leckhampton onwards have been plotted—that is, as regards their distances apart—on the beforementioned line from Leckhampton to Cold Comfort, due E. All these plottings are done in Table VI., the basis of which is, first, the line of country from Mount Surat to Leckhampton; and secondly, that from Leckhampton to Cold Comfort; both being shown by the plain lines in the diagram. Added to this, however, are some of the results, on the line from Kimsbury to Cold Comfort, which crosses the other line at Birdlip; and this line has been extended, as it were, from Kimsbury Castle so as to pick up some places to the south-west. The results are shown by the crossed lines (≠≠). In one case the same locality has been plotted in reference to both lines of country—namely, Buckholt Wood (Cranham); and as it is brought into position in regard to two different lines its relative distance from Birdlip and other places is affected. It therefore occurs twice in the plotted diagram, and is shown linked by the loops (<>).[1] Further, it may be noted that places on the two lines have been used to interpret each other; thus Sheepscombe has been interpreted by Kimsbury Castle, Dunley by Buckholt Wood.

Yet a third line of country may be noted, though it does not require any plotting on a diagram—namely, Kimsbury Castle to Bull Bank,[2] beyond Miserden. This line is nearly at right angles to that from Mount Surat to Birdlip. At Kimsbury Castle there are at least 28 feet of 'intervening beds,' at Bull Bank nothing. The line connecting these two places would pass almost exactly through the Sheepscombe section (No. VI., p. 401), and, drawn from 28 feet at the former place to nought at Bull Bank, it would leave Sheepscombe without any Gryphite-grit. However, Sheepscombe does show Gryphite-grit; but how much is uncertain: it has lost the Notgrove Freestone. Apparently it only possesses the base of the Gryphite-grit; but I have been unable to obtain any further details as a reward for the exploration of the country between Sheepscombe and Miserden. Sheepscombe has, however, been plotted on this assumption—that it shows only the base of the Gryphite-grit seen at Kimsbury Castle.

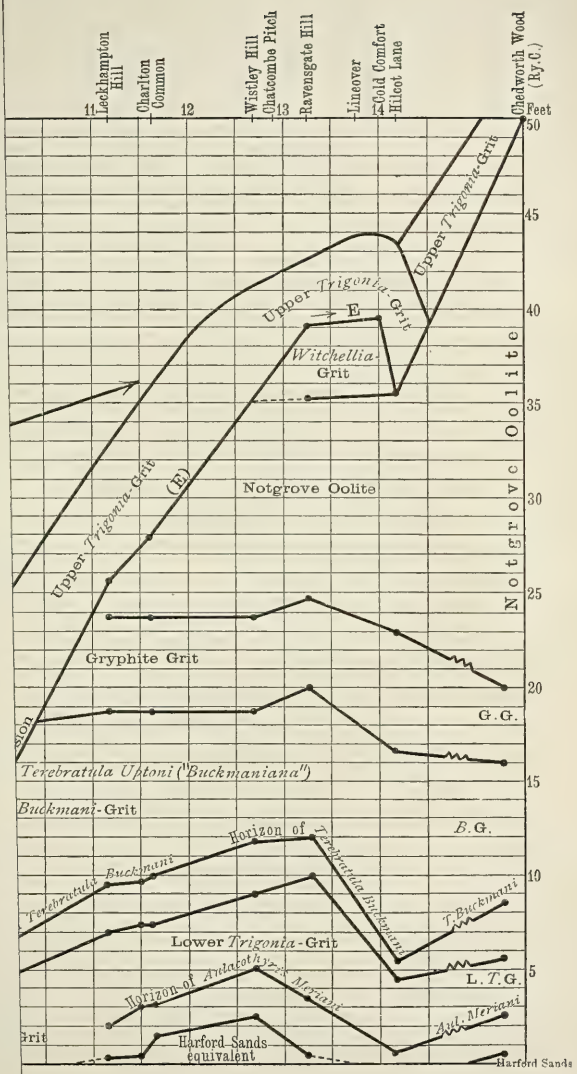
In further explanation of the plotted Table it may be noted that

[1] Two diagrams, each for their separate line of country, would have been clearer; but such diagrams make expensive blocks, and therefore details have been given in one only.

[2] There is an interesting section on Bull Bank Common, on the right of the road from Miserden to Duntisbourne Abbots (incorrectly spelt on the Ordnance Survey-map as 'Duntshorn'). It shows the *Clypeus*-grit well, and clay (Fuller's Earth) above.

[*To face* p. 430.

RAM.



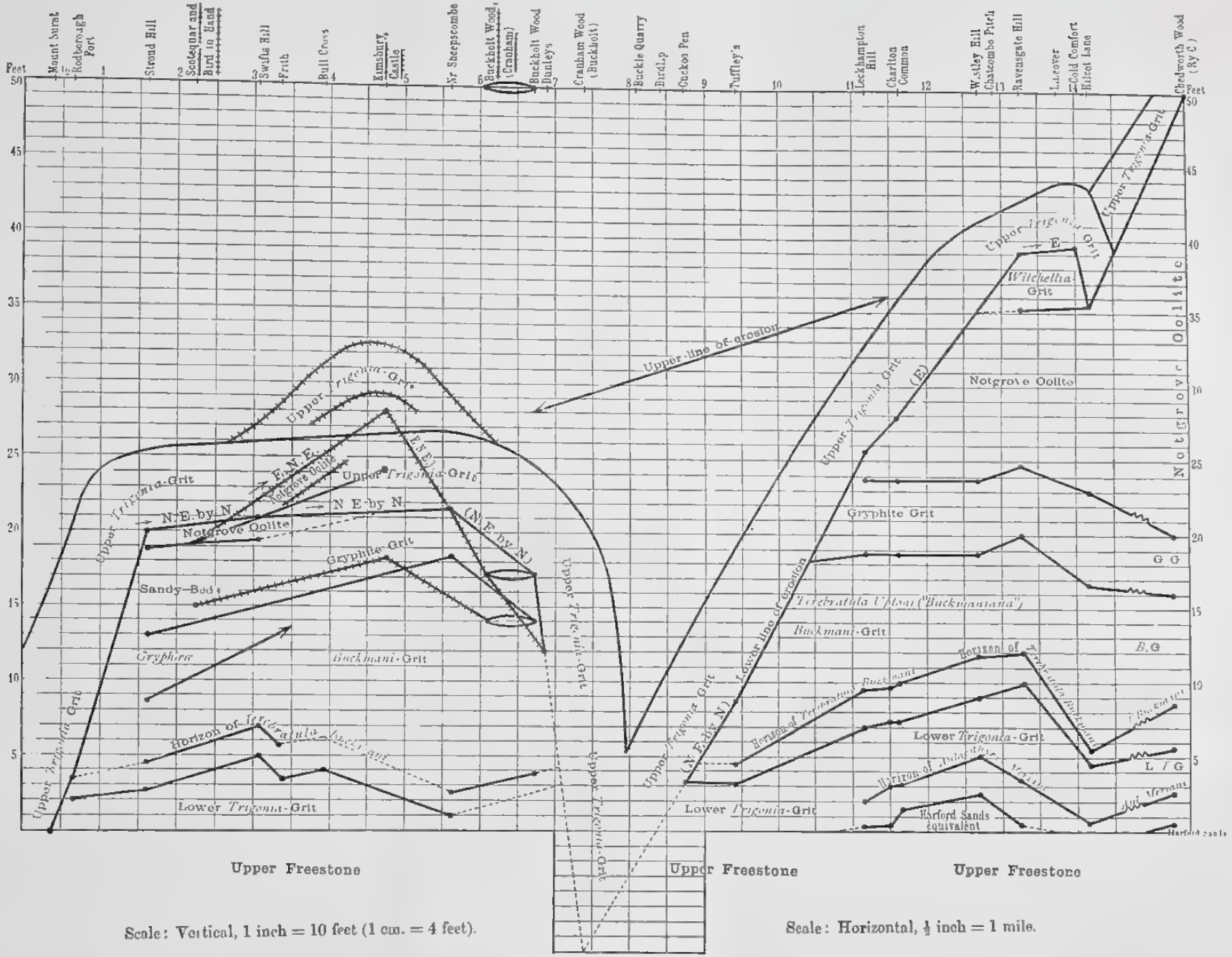
Upper Freestone

ale: Horizontal, $\frac{1}{2}$ inch = 1 mile.

of deposit. The line marked 'Horizon of *Terebratula* any localities, the species is found so plentifully. It mbe in conformity with the Kimsbury Castle section.

[*To face* p. 430.

TABLE VI.—STRATIGRAPHICAL DIAGRAM.



Note.—The upper boundary of the Upper *Trigonia*-grit is not intended to denote any particular thickness of deposit The line marked 'Horizon of *Terebratula Buckmani*' is intended to show the position of the marl-bed, below the sand-bed, wherein, at many localities, the species is found so plentifully. It should be dotted at Buckholt Wood, and from Wistley to past Hilcot. It is marked at Sheepscombe in conformity with the Kimsbury Castle section.

Table VI. (plain lines) shows a rapid rise in the thickness of the 'intervening beds' from Mount Surat to Stroud Hill. The thickness is maintained to Sheepscombe, and then a decline commences, which becomes very rapid between Buckholt and Cranham Woods. Next, after passing Birdlip, there is a rapid rise, the line for which travels nearly straight from Tuffley's to Ravensgate, the only deviation from straightness, it may be noticed, coinciding with a change of direction from about N.E. to E.

The important point for remark in Table VI. is what I may perhaps call 'the trough,' which has been cut through the 'intervening beds' in the neighbourhood of Birdlip by the Bajocian erosion. It will be seen that on each side of this trough, which is, of course, much exaggerated by the difference in the horizontal and vertical scales, the formations do not thin out; but that, as the 'intervening beds' increase in thickness, a higher formation is always brought in. Again, it will be observed that on each side of this trough the beds, when met with, stand at practically the same levels. Now these observations are important, because they prove that the trough is one of erosion, and is not due to any thinning out, or non-deposition of the beds at the time over the Birdlip area. Had the trough been due to the latter cause, a thinning of all the 'intervening beds' on each side of the trough would have been observable; and it would not have been the case that the uppermost of the 'intervening beds' was always absent where the thickness was less: on the contrary, all of the 'intervening beds' ought to be found, but each one of diminished thickness, or, if any were missing, the under and the middle beds would have just as much chance of being absent as the top one. Now it is seen that these conditions are not fulfilled, and that in each case upper beds do not make their appearance unless the full sequence of their predecessors have been completed.

It is therefore reasonable to conclude, and the diagram illustrates this assumption, that all the formations mentioned, the Notgrove Freestone, Gryphite-grit, etc., were at one time continuous from Cold Comfort and Leckhampton to Kimsbury Castle and beyond; and that at Leckhampton and Kimsbury Castle, and over the intervening area, the Notgrove Freestone was of fair thickness, say 10 to 12 feet. It is also very probable that the *Witchellia*-grit extended over this same district. Perhaps, too, there were beds of later date than the *Witchellia*-grit, yet earlier than the Upper *Trigonia*-grit, but they were completely denuded. The *Witchellia*-grit has been preserved over only a very small extent of country—what with erosion before the deposition of the Upper *Trigonia*-grit,[1] and the much greater erosion of more recent date, it has been left over an area of only $1\frac{1}{2}$ square miles; so it very nearly happened that the *Witchellia*-grit was altogether lost. What came about so

[1] This Bajocian erosion was quite unexpected, and it is different from what I have surmised elsewhere; but there must, of course, have been areas of non-deposition, only more to the south-east: 'The Relations of Dundry with the Dorset-Somerset and Cotteswold Areas during part of the Jurassic Period,' Proc. Cottesw. Nat. Field-Club, vol. ix. (1889) p. 383.

nearly in this case may have been the actual fate of its successor. If the successor have been preserved anywhere, it should be in the Northern Cotteswolds.[1]

The crossed lines in Table VI. show some of the results obtained along another line of country—Kimsbury Castle to Cold Comfort: the most noticeable points being a generally greater thickness of the 'intervening beds' as a whole, and the preservation of a greater amount of Notgrove Freestone. As this line, before it reaches Birdlip, lies west of the Mount Surat–Leckhampton line, it shows that to the westward the 'intervening beds' were thicker, and that the Notgrove Freestone had suffered less from denudation towards the west.

If the whole of the results obtained from this line of country had been given in a diagram to compare with the Mount Surat–Leckhampton line, it would have been seen that the lines bounding the trough in the latter run very much straighter than those in the former; in fact, the bend in the latter on the Leckhampton side is only where the direction changes beyond Leckhampton from N.E. to E. But the greater straightness would appear to indicate this —the Mount Surat–Leckhampton line cuts the trough at right angles, while the bending of the boundaries in the Kimsbury–Cold Comfort line shows that this run of the country is at an oblique angle to the trough of erosion. This seems to give a clue to the direction of the trough—namely, that it was at right angles to the line of country plotted by plain lines in Table VI.

[1] In Table VI. I have marked two lines of erosion—an upper and a lower one. The latter corresponds to the 'trough' which has just been treated of, and this 'trough' seems to be repeated in the Stroud Valley, one of its sides being shown by the rapid rise in the line of beds from Mount Surat to Stroud Hill. But then there is the upper line of erosion from Stroud Hill to Sheepscombe marked by the letters N.E. by N. (with arrow thus, → N.E. by N., not those in parentheses), the direction taken. In the direction E.N.E., from Scotesquar to Kimsbury Castle, the upper line of erosion takes a course such as to point to there having been less erosion to the west of the first line; and with this the greater thickness of Notgrove Freestone at Kimsbury Castle tallies. Then another direction for the upper line of erosion would be S.E. by E. from Kimsbury Castle to Sheepscombe, a dip, according to present data, of about 6 feet in 2½ miles (not the line shown in the diagram). Now the two lines of erosion N.E. by N. and E.N.E. do not coincide with the line of erosion shown by the sides of the Birdlip trough; and it is therefore to be assumed that the Bajocian erosion effected two things: first, it planed the country down to a general level represented in the directions taken by the lines marked N.E. by N. and E.N.E., and roughly by the line drawn across the Birdlip trough, marked 'Upper line of erosion,' which is about the mean of the two lines N.E. by N. and E.N.E., and nearly coincides with the top of the *Witchellia*-grit on the right hand of the diagram; secondly, it excavated local 'troughs,' as indicated by the steep line, marked 'Lower line of erosion,' dipping to Birdlip, and also by the line dipping from Stroud Hill to Mount Surat; these two troughs being connected *viâ* Miserden, the dip to which, from Sheepscombe, would be about 22 feet in 3½ miles, very similar to the erosion-dip from Leckhampton to Tuffley's. The placing of this matter in a clearer light must be left to another paper, when continuous lines of country can be plotted. Here it will be noticed that the upper line of erosion marked on the diagram does not coincide either with the N.E. by N. or the E.N.E. line, because the continuation of both is a line east.

Another thing should be noticed—the continuation of the boundary-lines makes them meet at a point south-west of Cranham Wood. Now it is known that at Cranham Wood the Bajocian erosion not only cut through the 'intervening beds,' but even began to destroy the Upper Freestone or Oolite Marl series, down nearly to the line where *Terebratula fimbria* is fairly common It is obvious, too, that at Cranham Wood was found the lowest point of the erosion; and therefore the meeting of these lines at this point is another argument in favour of the Mount Surat–Leckhampton line being at right angles to the trough eroded.

Quite different is the state of affairs along the other line of country, where both the boundary-lines would have had to be continued at a different angle—to make them accord with the fact of there being not only total removal of the 'intervening beds,' but also removal of some of the Upper Freestone at Cranham Wood.

As to the date when all this denudation took place, it is possible to fix it within very narrow limits. Using the chronological term proposed in my former paper—hemera—it can be said that the denudation was hardly likely to have commenced before the end of the *Witchellicæ* hemera; because strata of this hemera are found in the district. The erosion must have gone on during the hemeræ which elapsed between the *Witchellicæ* and the *Garantianæ* hemeræ (the latter was the time of the deposition of the Upper *Trigonia*-grit); and it must have come to an end before the strata of the *Garantianæ* hemera were deposited, because the Upper *Trigonia*-grit is found lying on the eroded surfaces, and the Upper *Trigonia*-grit rests successively, according to locality, on Upper Freestone, Lower *Trigonia*-grit, etc., up to *Witchellia*-grit. Now, it was shown in my former paper that the time which elapsed between the *Witchellicæ* and *Garantianæ* hemeræ could be divided into the following hemeræ:—*Sauzei*, *Humphriesiani*, *niortensis*. Therefore this erosion took place during some or all of those hemeræ, because no strata of those hemeræ have yet been found in the Cotteswolds, and there are certainly none in the district now under review.[1]

The comparison of the Cotteswold strata with those of Dorset set forth in Table II. (p. 422) will bring this matter clearly before the

[1] Some years ago Mr. H. B. Woodward, F.G.S., kindly gave me a *Stephanoceras* collected by Prof. R. Tate from Rodborough, and identified as *Ammonites Humphriesianus*. In his 'Lower Ool. Rocks,' Geol. Surv. Mem., Jurassic Rocks, vol. iv. p. 111 (1894), Woodward speaks of Prof. Tate's find as evidence for the *Humphriesianus*-zone in the Cotteswolds; but the species is no more like *Humphriesianus* than it is like *pettus* of the Middle Lias. So wide an use of the name *Humphriesianus* would justify calling Middle Lias *Humphriesianus*-zone; but when the term '*Humphriesianus*-zone' is used it means a restricted series of beds deposited contemporaneously with the Coronaten-Schichten of Quenstedt. *Stephanocerata* occur in several beds besides the Coronaten-Schichten, and consequently the finding of a *Stephanoceras* is no evidence for the *Humphriesianus*-zone *sensu stricto*. No beds contemporaneous with the Coronaten-Schichten of Quenstedt have been discovered as yet in the Cotteswolds. At Rodborough the gap between beds 2 and 3 is very considerable. Other sections in the district fill it in to a certain extent; but even they do not show any beds of the *Humphriesianus*-zone, much less, therefore, can Rodborough.

reader. According to that Table the lapse of three hemeræ is unrepresented by any deposit yet noted in the Cotteswolds. It is, however, in every way probable that strata were deposited in the basin during these hemeræ—perhaps northwards of any now preserved. An interesting speculation may therefore be indulged in—namely, what thickness would such deposits have attained. One estimate we may obtain from Tables I. and III. (pp. 420, 426), the former giving nearly 14 times the thickness of deposit in the Cotteswolds compared with Dorset in the same length of time, the latter yielding as much as 22 times, and yet being incomplete. Another estimate might be obtained by taking the maximum thicknesses ascertained in Dorset of the same strata as those here tabled, namely about 13 feet, which is rather more than one-third that of the Cotteswolds; and yet another by taking the total of maximum developments of Cotteswold 'Inferior Oolite,' which would probably work out to about 400 feet (but exact data have not been collected), and comparing them with the Dorset total of 130 feet.[1] However, in choosing which of these estimates to adopt, it must be remembered that the deposits in Dorset for which the probable Cotteswold equivalent thicknesses are desired are not maxima deposits, for the reason that they are very fossiliferous. Therefore the first and last estimates seem the best to take. Now the strata in Dorset deposited during the *Sauzei*-, *Humphriesiani*-, and *niortensis*-hemeræ are about 7 feet thick; it is therefore possible to say that if the Cotteswold sequence had been complete it should have had an extra thickness of at least $7 \times 4 = 28$ feet, or more possibly of 7×14: that is, 98 feet.

The difference between these figures may seem considerable; but it is a point gained if the student of Cotteswold geology learn to think that its sequence of 'Inferior Oolite' is incomplete by something between 28 and 98 feet of rock. There is something, however, of far more importance which warrants the above speculation. In any estimate of the time-value of a hemera, or of a series of hemeræ, or in any comparison of one series of hemeræ with any other series, the only legitimate measure is the maximum amount of work done by way of deposition in any given time, just as the only comparison of the powers of two racers before they meet is their time over the same distance at utmost speed. No attention can be paid to anything less than maxima; but it may be conceded that maxima of limestone, of sand, and of clay-deposits would have different values. If, then, the same length of time be represented in the Cotteswolds by a limestone-deposit 14 times as thick as it is in Dorset, any estimate of that length must be based upon the greater thickness. Now the Cotteswold 'Inferior Oolite' strata are very considerably thicker than those in Dorset; but, as this paper shows, they are incomplete. Before undertaking any estimate of the time-value of the series of hemeræ, it becomes necessary to make some speculation to supply the deficiency; and that speculation gives a thickness of from 28 to 98 feet as wanting.

[1] 'Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 506.

In my former paper the length of time taken up in depositing the 'Inferior Oolite' was divided into 12 hemeræ: now this is increased to 13, with indications that yet more subdivisions may be required. Of the exact correlation between the deposits in different basins which can be made by the hemeral system I offer this paper as evidence.

It is now 35 years since Wright, in the conclusion of a paper read before this Society, remarked[1]:—'The existence of three different faunas in the Inferior Oolite is evidence that a long period of time elapsed during the accumulation of this formation.' How much more strongly does the case stand to-day when it is seen that 13 different faunæ can be traced over a very considerable area! I do not know what estimate has usually been formed concerning the comparative length of time required for the deposition of the 'Lias' and the 'Inferior Oolite' respectively; but seeing that when the latter was divided into 3 zones the former was partitioned into 15,[2] the inference is that the time for the former was 5 times as great. If the Lias zones (stratigraphical divisions) be translated into hemeræ (time-divisions), then 15 hemeræ for the 'Lias' and 13 for the 'Inferior Oolite' would probably state the relative lengths of time more truly. The 'Lias,' both at home and abroad, had certainly received very much more attention than the Inferior Oolite, while it is fossiliferous and ammonitiferous where the deposits are thick: it is not likely that even minute work would require the division of Liassic time into a much greater number of hemeræ than of zones now recognized. On the other hand, the great increase for the Inferior Oolite—from 3 to 13 divisions—is due to the fact that its beds are now receiving attention more nearly equal to that formerly given to the Lias.

That the Inferior Oolite only obtained 3 divisions in the first place is due to this, that where its deposits are thickest and had been most carefully investigated, they are frequently unfossiliferous and, generally, non-ammonitiferous. At present, however, our knowledge of the strata deposited during either of these epochs, 'Lias' or 'Oolite,' is, except in regard to a few favoured localities, very incomplete; while the majority of records are useless from want of precision. If any estimate is to be formed of the comparative length of time occupied in the deposition of 'Lias' and 'Oolite,' or any portions thereof, we require a knowledge of the various deposits made during the different hemeræ, and especially a knowledge of the maximum thicknesses attained. It is partly as a contribution towards this end—a very incomplete contribution, it is true—that the present paper is offered.

[1] 'Inferior Oolite,' Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 48.

[2] Wright, 14 or 15; the number has varied considerably in both cases, but to the 'Inferior Oolite' has always been given far the fewer number of divisions.

Appendix to Parts I. & II.

1. The Geographical Extent of the 'Intervening Beds.'

Although the district has not been examined in sufficient detail, a few observations may nevertheless be made in this connexion. There would be no difficulty in tracing the geographical areas of the different 'intervening beds,' and it may be an interesting field of future research. Meanwhile it may be noted that the following localities show no deposit of 'intervening beds'—namely, Selsley Hill, Mount Surat, Miserden (Bull Bank), Cranham Wood; that they form, if connected by lines, a rough semicircle or rather more, somewhat adjacent to the present course of the River Frome; that within, namely to the north-east of this semicircular line, the 'intervening beds' (the semicircle being their boundary) extend till they are cut off by the escarpment of the Hill-flank overlooking the Severn Valley.

Then there is another line which begins at Birdlip, with no intervening beds, and this probably goes south of Rendcomb,[1] certainly south of Chedworth Wood, where the 'intervening beds' are so well developed (see p. 425), and afterwards must bend to between Harford and Little Risington, for at the latter place *Clypeus*-grit rests on clay—presumably Upper Lias.[2] Thus the 'intervening beds' of the Middle and Northern Cotteswolds are cut into two parts by a trough with a north-westerly direction at Birdlip, and they are bounded by two arcs radiating thence to the south-east and north-east respectively.

2. The Geographical Extent of the *Witchellia*-grit.

It is reasonable to assume that the *Witchellia*-grit extended over as wide an area as the other 'intervening beds,' and therefore it would have occupied a large portion of the Mid-Cotteswolds. It must also be remembered that the sea which deposited the *Witchellia*-grit must have had communication with Dundry[3] and with Dorset. Now, what with the Bajocian denudation from which the *Witchellia*-grit suffered very greatly, and with Quaternary denudation which has removed it from places where it escaped the Bajocian denudation, this deposit occurs in the Middle Cotteswolds over a very limited area. It is evident that the Bajocian denudation removed it from

[1] A roadside section at Rendcomb afforded, so far as I could ascertain, only 7 inches of Lower *Trigonia*-grit as the 'intervening bed,' and this was much bored; but it may be remarked that the section is much overgrown, and no very definite palæontological evidence was obtained.

[2] Hull, 'The Geology of the Country around Cheltenham,' Mem. Geol. Surv. 1857, p. 47.

[3] From Cold Comfort to Dundry is a distance of 42½ miles direct, and no *Witchellia*-beds occur in the interval; but the connexion may not have been direct.

Charlton Common and from Chatcombe Pitch,[1] while from a locality about ½ mile south-east of the Seven Springs it has taken all the Notgrove Freestone as well, and the *Witchellia*-grit is absent from Pegglesworth Hill, and from Ossington Hill 1½ miles east-by-north of Andoversford: so the southern boundary, as it was left by the Bajocian denudation, lies on, or just to the north of a line connecting these places. But Quaternary denudation has done much to narrow down even that small extent; and so the result is that south of the valley of the Chelt the *Witchellia*-beds are reduced to a small patch, which in extent cannot exceed 1½ miles long by 2 furlongs broad—the length being from east of Wistley Hill to just beyond the eleventh milestone from Gloucester on the Oxford road. Whether the *Witchellia*-beds are met with at Cleeve Hill I cannot yet say; and it is to be hoped that they may be preserved elsewhere in the Northern Cotteswolds. (See Postscript, p. 461).

3. *Ostrea sublobata*, Deshayes,[2] *Gryphæa cymbium*, J. Buckman,[3] *Gryphæa Buckmani*, Lycett,[4] *Gryphæa sublobata*, auctorum.

A *Gryphæa* from the intervening beds was first figured by J. Buckman as *Gryphæa cymbium*. Subsequently Lycett gave to the shell, taking this figure as his type, the name *Gryphæa Buckmani*. Later still this name was dropped in favour of *Gryphæa sublobata* (Deshayes), which has of recent years always been applied to the *Gryphæa* of the Gryphite-grit. It is to be noticed that the *Gryphææ* tend to alter in the later deposits of the 'intervening beds,' becoming broader, more circular, and having a more pronounced expansion. Now the dimensions of the fossil given by Deshayes in his description (no figure) are: length 80 mm., breadth 50 mm. These proportions do not agree with the dimensions of *Gryphæa Buckmani*, which is shown by the figure to be 70 mm. long and 65 mm. wide: it is evidently a fossil from the lower of the 'intervening beds,' because the specimens from the lower beds generally conform to such dimensions. Still less do the proportions given by Deshayes agree with those of the Gryphite-grit specimens. Six examples of these give the following proportions:—

	1	2	3	4	5	6
Length[5]	81	88	80	79	64	74 mm.
Breadth	90	87	79	78	69	69 mm.

[1] The quarry from which the section of Chatcombe Pitch was taken has now been worked out entirely, so that it might not be easy to obtain the details given (p. 415). Notgrove Freestone is, however, to be seen by the roadside, and this appears, from somewhat obscure exposures farther east in the bank, to be capped directly by Upper *Trigonia*-grit—at least that bed rests on a bed of bored freestone, somewhat shelly. The *Witchellia*-grit is, therefore, apparently absent from here.

[2] Encyclop. méth. (Hist. Nat. des Vers) vol. ii. (1830) p. 307.

[3] Murchison's 'Geology of Cheltenham,' 2nd ed. 1845, pl. vii. fig. 3.

[4] '*Gryphææ* of the Gryphite-grit,' Proc. Cotteswold Nat. Field-Club, vol. i. pp. 235–236.

[5] To accord with Deshayes's use of the terms. In modern nomenclature the breadth is the length, and *vice versa*.

The last is a differently-shaped fossil, with the 'wing' much more distinctly separated.

It would appear from the measurements that there may very reasonably be some doubt as to whether Lycett's *Gryphæa Buckmani* is really the same as the *Gryphæa sublobata* (Deshayes); but there cannot be much doubt that the Gryphite-grit fossils are distinct. Further, the *Gryphæa Buckmani* is not the true Gryphite-grit form. It has, no doubt, developed into the rounded form, because with age there is a tendency to broaden and to make the separation of the wing less definite. The change from *Gr. Buckmani* into the broad form may have been very gradual, so that most likely both forms will be found occurring together; but in the lower of the 'intervening beds' it would probably be found that the long form was the most prevalent, and in the upper that the rounded form has entirely taken its place. To ascertain, however, the vertical range of the different forms would require systematic collecting of these *Gryphææ*, and the noting of their exact horizons, from different localities. The round form probably requires a name as a distinct mutation.

4. Gryphite-grit.

I would call attention to certain remarks in connexion with this deposit at Kimsbury Castle: namely, that the beds are considerably bored and that polyzoa are attached to the *Gryphææ* both inside and out (p. 403). Now, the presence of the *Gryphææ* alone points to a very slowly accumulating deposit; and these other signs bear additional testimony thereto. But that the Gryphite-grit was a slowly-formed deposit is of importance in connexion with its contemporaneous equivalent in Dorset. That deposit is in many places about one-sixth the thickness. Therefore the Gryphite-grit was deposited 6 times as fast as the Dorset bed; and yet the Gryphite-grit was laid down very slowly.

At Leckhampton Hill and Charlton Common the thickness of the Gryphite-grit has been stated at 5 feet. This may be regarded as a somewhat approximative measurement, which may appear too much or too little according to whether the rock be well weathered, so that the *Gryphææ* are prominently shown, or whether it be freshly exposed. But between the sandy beds of the *Buckmani*-grit containing broad '*Terebratulæ* aff. *Buckmaniana*,' and the white oolitic stone of the Notgrove Oolite are about 5 feet of very gryphæiferous ragstones. The change from the *Gryphæa*-beds to the Notgrove Oolite is well marked, but from the sandy beds of the *Buckmani*-grit to the gryphæiferous beds it is not always abrupt—indeed, it is generally somewhat gradual. The broad *Terebratula* referred to above occurs about 7 feet below the base of the Notgrove Oolite. The sequence from *Buckmani*-grit to Notgrove Oolite may be observed at the west end of Charlton Common; but the *Buckmani*-grit is not complete.

Part III.

The Chronological Sequence of the Brachiopod-faunæ in the Cotteswolds and in Dorset.

In the discussion to which my former paper gave rise it was urged that the deposits of certain divisions (hemeræ) could not be followed in the Midlands. I see, however, no reason why this should be the case. Of course, if fossil evidence be scanty the difficulty of stating just what deposits were laid down during particular hemeræ becomes increasingly embarrassing—just as the Cotteswolds require far more work for their investigation than Dorset, added to greater natural difficulties of locomotion, except in regard to a few favoured localities; but it is only a question of more prolonged study. From other remarks which have been made to me, it seems to be thought that an absence of ammonite-remains would render the work impossible; but this again is an incorrect assumption. If ammonites be scarce, correlation must be accomplished more or less indirectly. Thus the Midlands might be correlated with, say, the Cotteswolds by means of their brachiopod or other fauna, and then, the correlation of Cotteswold and Dorset deposits being known, the exact correlation of the Midland beds would be apparent. But if certain Midland localities and deposits yield only an occasional ammonite, then the date of the ammonitiferous deposits would be fixed directly, and the date of other non-ammonitiferous deposits would be inferred from the fauna associated with the ammonites. Thus the ammonites would be a direct medium of exchange, the other fauna an indirect one. This is the plan which has largely been pursued in the Cotteswolds. Once there has been a definite and exact record of the ammonites which are associated with any particular part of the fauna—say the brachiopod portion—appeal need not be made to ammonites at all.

Of course, in the first place, for correlation between Dorset and Gloucestershire, ammonites are practically the only medium of exchange, but when it was known that certain strata of the Cheltenham or Stroud districts were, by the evidence of ammonites which they yielded, deposited during certain hemeræ, then strata of other Cotteswold localities, though not yielding any ammonites, could be correlated with Dorset. First they can be correlated with the Cheltenham or Stroud beds by means of their brachiopods, and then, as those have been already correlated with Dorset, the strata of the other localities may be compared therewith. For local Cotteswold correlation the brachiopods are amply sufficient, if carefully collected. They are not of quite so much value as ammonites for small divisions, because generally their chronological range was more extensive; but it was sufficiently restricted in all cases to make them very good indicators.

These remarks also apply to other divisions of the fauna. Gasteropoda or lamellibranchiata may be selected by those who have studied them, and similar work might be done in the correlation of

Table VII.—The Chronological Succession of the Brachiopod-faunæ.

COTTESWOLDS.			DORSET-SOMERSET (South of the Mendips).		
	Great Oolite, Gloucestershire,	Fullers' Earth Rock, Dorset, with *Macrocephalites subcontractus* and *Macroc. Morrisi* (Oppel). [(M. & L.).	*Terebratula linguifera*, S. Buckm. *T. globata*, Sow.	*Zeilleria ornithocephala* (Sow.). *Z. triquetra* (Sow.).	*Rhynchonella Smithii*, Walker.
Zeilleria ornithocephala (Sow.). *Eudesia cardium* (Lam.).	Fullers' Earth,		*Terebratula* cf. *decipiens*.		*Rhynchonella Smithii*, var
	Names of Cotteswold Beds.	Hemeræ.			
	Limestone-beds above *Clypeus*-grit.	*Fuscæ*.	*Terebratula sphæroidalis* (Sow.). *T. Phillipsi*, Morris [Walker].	*Aulacothyris* cf. *Meriani*.	
	.....	*Zigzag*.	? *Terebratula sphæroidalis*.		? *Acanthothyris panacanthina*, B. & W.
'*Terebratula globata*,' Cotteswold form, in innumerable variety. *T. birdlipensis*, Walker. *T. Fleischeri*, Oppel. *T.* aff. *marmorea*, Oppel [Upton].	The *Clypeus*-grit itself.	*Truellii*.	*Terebratula Stephani*, Dav. *T. sphæroidalis*, Sow., very large. *T. decipiens*, Desl. *T. Phillipsi*, Morris. *Dictyothyris hybrida*, Desl.	*Zeilleria Waltoni* (Dav.). *Z. emarginata* (Sow.). *Z. Hughesi* (Walker). *Aulacothyris carinata* (Lam.), common. *A. crewkerniensis*, S. Buckm.	*Rhynchonella plicatella* (Sow.). *R. subtetrahedra*, Dav. *R. parvula*, Desl. *Acanthothyris spinosa* (Linn.), rather small. *A. panacanthina*, Buckm. & Walker.
Zeilleria Hughesi (Walker) [Upton]. *Aulacothyris carinata* (Lam.) [Upton].					

Terebratula globata, generally smaller and more spheroidal than in the *Clypeus*-grit. *Terebratula* between *decipiens* and *sphæroidalis* in shape (local) (S. of Stroud).	*Zeilleria Hughesi* (Walker). *Z. Waltoni* (Dav.). *Z. emarginata*, Sow. [Walker]. *Aulacothyris carinata*, Lam.	*Rhynchonella angulata* (Sow.). *R. subtetrahedra*, Dav. *R. lumpenensis*, S. Buckm. *Acanthothyris spinosa* (Linn.), very large.	The Upper *Trigonia*-grit.	*Garantianæ.*	*Terebratula Phillipsi*, Morris. *T. sphæroidalis*, Sow. *T. Ferryi*, Desl. *T. Hollandæ*, S. Buckm. *T. globata*, Sow. *T. decipiens*, Desl. *T. Stephani*, Dav. *Dictyothyris Morieri* Dav.	*Zeilleria Waltoni* (Dav.). *Z. emarginata* (Sow.). *Aulacothyris carinata* (Lam.). *A. bisulcata* (S. Buckm.). *A. crewkerniensis* (S. Buckm.).	*Rhynchonella plicatella* (Sow.). *R. parvula*, Desl. *Acanthothyris spinosa* (Linn.), large. *A. obornensis*, B. & W.
				Niortensis.	*Terebratula Craneæ*, Dav. *T. gravida*, Szaj. *T. sphæroidalis*, Sow. *T. Phillipsi*, Morris.	*Plesiothyris reversa*, S. Buckm. *Glossothyris curviconcha*, Oppel.	*Rhynchonella plicatella*, Sow.
				Humphriesiani.	*Terebratula Craneæ*, Dav. *T. Hollandæ*, S. Buckm. *T. gravida*, Szaj. *T. sphæroidalis*, Sow. *T.* aff. *Buckmani*, but flat and more transverse, with plicate derivatives aff. *Buckmaniana.*	*Plesiothyris Brodiei*, S. Buckm. *P. reversa*, S. Buckm. *Glossothyris curviconcha* (Oppel). *Aulacothyris Haasi*, S. Buckm.	*Rhynchonella dorsetensis.* Buckm. ? *R. dundriensis*, S. Buckm.
Terebratula Phillipsiana, Walker [1] *T. Buckmaniana*, Walker.	*Zeilleria* aff. *Leckenbyi.*	'*Rhynchonella* which Davidson identifies as *quadriplicata*' [Upton]. *Acanthothyris* sp.	*Phillipsiana*-beds of Cleeve Hill.	*Sauzei.*	*Terebratula ventricosa*, Zieten, with plicate derivatives as shown by Deslongchamps.	*Acanthothyris paucispina*, B. & W.	
Terebratula Wrighti, Dav.		*Acanthothyris* sp. *A.* aff. *tenuispina.*	*Witchellia*-grit and Notgrove Freestone.	*Witchelliæ.*	*Terebratula ventricosa*, Zieten. *Terebratula* sp. *T.* cf. *globulus*, Waagen.	*Rhynchonella*, various species. *Acanthothyris* cf. *tenuispina.* *Acanthothyris* sp.	

[1] [These species occur in the *Phillipsiana*-beds of Cleeve Hill. I am alone responsible for their present position—corrected since the paper was read, in accordance with recent work; see Postscript, p. 461. They are found superior to a bed with *Terebratula Wrighti*, but they may not have lived quite so late as the *Sauzei* hemera. I should mention that Wright (Quart. Journ. Geol. Soc. vol. xvi. 1860, p. 5) placed the beds with *Terebratula Phillipsi* (=*Phillipsiana*), not only below the Lower *Trigonia*-grit, but below his *Chemnitzia*-grit. This is maintained in subsequent papers; and the bed is said to be the equivalent of the Upper Freestone of Leckhampton ('Correlation of Jurassic Rocks, etc.' Proc. Cotteswold Nat. Field-Club, vol. v. 1870, p. 143; 'Monogr. Lias Ammonites,' pt. iii. Pal. Soc. vol. xxxiv. 1880). Mr Upton, however, who is a very careful observer, struck by the biological affinities of *Terebratula Phillipsiana* and the sandy matrix, suggested that these beds were above the Lower *Trigonia*-grit, correlating them with the *Buckmani*-grit of the Stroud district; and, when this paper was written, the species were placed in accordance with his suggestion.—April, 1895.]

TABLE VII. (*continued*).

COTTESWOLDS.			NAMES OF COTTESWOLD BEDS.	HEMERÆ.	DORSET–SOMERSET (SOUTH OF THE MENDIPS).		
		Acanthothyris aff. *Crossi* (Walker).	Gryphite-grit.	'*Sonniniæ*.'			
Terebratula Buckmani, Dav. *T. Uptoni*, sp n. *T. crickleyensis*, sp. n.		*Rhynchonella* aff. *balinensis*. *Acanthothyris* sp.	*Terebratula Buckmani*-grit.	Post-*discitæ*.[2]	*Terebratula cortonensis*, S. Buckm.		
	Aulacothyris Meriani (Oppel).	*Rhynchonella* sp. *Rhynchonella balinensis*, Szajn.	Lower *Trigonia*-grit.	*Discitæ*.	*Terebratula cortonensis*, S. Buckm. *T. Eudesiana*, S. Buckm.	*Zeilleria disculus* (Waagen).	*Rhynchonella Forbesi*, Dav. *R. buteo*, Szajn. *R. balinensis*, Szajn. *R. liostraca*, S. Buckm. *Acanthothyris cortonensis*, Buckm. & Walker.
			Harford Sands.	*Concavi*.	*Terebratula Eudesi*, Oppel.		*Rhynchonella Forbesi*, Dav.
Terebratula fimbria, Sow.; plicate and aged.		*Rhynchonella cynomorpha*. *R. Tatei*.	The Upper Freestone.	*Bradfordensis*.	*Terebratula perovalis*, Sow. *T. ampla*, J. Buckm.		
Terebratula fimbria; common.		*Rhynchonella subobsoleta*; common.					
Terebratula fimbria, scarce. *T. plicata* (very plicate). *T. Whitakeri*, Walker. *T. notgroviensis*, S. Buckm. *T. submaxillata*, Dav.	*Glossothyris*(?) *curvifrons* (Oppel). *G. galeiformis*, M'Coy. *Zeilleria Leckenbyi* (Walker); common. *Z. Witchelli*, S. Buckm.	*Rhynchonella Lycetti*, Dav. *Rhynchonella* sp.	The Oolite Marl.		*Terebratula Eudesi*, Oppel. *T. shirburniensis*, S. Buckm.	*Glossothyris Brebissoni* (Desl.). *G. provincialis* (Desl.).	*Rhynchonella ringens*, Dav.

Terebratula pisoli'ica, S. Buckm. (common). *T. fimbria*; rare and feebly plicate.	*Zeilleria Leckenbyi* (rare).	? *Rhynchonella oolitica*. *Rhynchonella* aff. *subangulata*; common.	The Lower Freestone.			
Terebratula plicata, J. Buckm.; common. *T. simplex*, J. Buckm. *T. submaxillata*, Dav.	? *Eudesia leckhamptonensis* [Walker].[3]	*Rhynchonella subangulata*, Dav. *Rhynchonella* sp. *R. oolitica*, Dav.	The Pea-grit.	*Murchisonæ.*	*Terebratula perovalis*, Sow. *T. conglobata*, Desl. *T. simplex*, J. Buckm.	*Zeilleria anglica* (Oppel).	*Rhynchonella subangulata*, Dav. *R. subringens*, Dav. *R. palma*, Szajn. *R. cymatophora*, sp. n. *R. Brasili*, sp. n.
Terebratula simplex. *T. Whitakeri*, Walker [Upton]. *T. plicata*. *T. perovalis*, Sow.	*Aulacothyris* sp.	*Rhynchonella* sp. *R. oolitica*, Dav.	The Lower Limestone.[4]				
Terebratula perovalis, Sow. *Terebratula* between *haresfieldensis* and *perovalis*. *T. euides*, S. Buckm. [Upton].	*Aulacothyris* aff. *Blakei* (Walker).	*Rhynchonella subdecorata*, Dav. *R. Wrighti*, Dav. *R.* aff. *cynocephala*.	The sandy ferruginous beds.	*Scissi.*	*Terebratula euides*, S. Buckm. *T. Etheridgii*, Dav. *T. Leesi*, S. Buckm.	*Zeilleria* cf. *anglica*.	*Rhynchonella* aff. *Weigandi*, Haas & Petri.

[2] This is given a separate position here, only on account of the importance of its brachiopod fauna in the Cotteswolds; ammonite evidence is wanting to show its separation from the *discitæ* hemera.

[3] This species is said to come from the Pea-grit (Walker in Davidson, Suppl. to the Monogr. Jurassic Brachiopoda, p. 185). There are two specimens in the Museum of Practical Geology with a pisolitic matrix; but perhaps it is *Clypeus*-grit. This would be far more likely than that the species should be so far removed from its ally *Eudesia cardium*. No confirmation of Mr. Walker's finds can be recorded.

[4] With regard to the Cotteswold beds, the Lower Limestone of the Stroud area is here taken as, in part, contemporaneously deposited with a portion of the Pea-grit of more northern localities, while the Pea-grit of the Stroud area is considered to be rather later than that of Leckhampton, and more nearly contemporaneous with the Lower Freestone; therefore the Lower Freestone of Stroud is considered to be more nearly contemporaneous with the lower part of the Oolite Marl of the Northern Cotteswolds, which is supposed to have begun earlier than that of Stroud (see p. 458). This will explain the placing of certain species opposite names such as Lower Freestone usually regarded as denoting 'unfossiliferous beds.'

non-ammonitiferous Jurassic deposits. Once a starting-point is obtained in a record of contemporaneity with ammonites at certain type-localities, the rest becomes an easy matter.

The brachiopod-fauna of the Cotteswolds is, on the whole, abundant. Compared with Dorset, the species are certainly fewer—less than one-half in my opinion, allowing for those undescribed—but individuals are undoubtedly more numerous: a rough estimate would place them at twice as many. This fact, added to the far greater accumulation of deposit in the Cotteswolds as compared with Dorset —often as many feet in the former as there were inches in the latter,—enables the collector to localize his horizons with very considerable ease and decided precision.

In order to show what has been done in this way I append (pp. 440–443) a table of the chronological sequence of brachiopoda in the Cotteswolds, and in Dorset–Somerset.[1] In regard to the latter the records are the result of my own work. They may in some cases require revision, because the specimens were mostly collected before so many divisions were attempted. In the Cotteswolds the records are in the main also the result of my own work; but I have had the great advantage of Mr. Upton's help in confirmation. Of Cotteswold brachiopoda Mr. Upton possesses a magnificent collection; he has been most precise in recording localities, and very observant in the matter of horizons; while he is equally discriminating in regard to species. Therefore I drew up this table and submitted it to him in MS. Certain additions are made on his authority, and to these his name is appended in square brackets —the same sign being used for any authority for horizon in other cases.

A comparison of the two sides of Table VII. shows that I have tabulated about 50 species for the Cotteswolds and 65 for Dorset; but the latter number is far fewer than that district is entitled to. I have collected in the Cotteswolds for a far greater number of years than in Dorset, and owing to the accessibility of certain places in the former region, on account of its proximity to populous towns, its strata have always received a very large amount of attention. The number of undescribed Cotteswold species is, therefore, somewhat small; but the number of undescribed Dorset species is very large. Taking a rough and, I think, by no means exaggerated estimate of the number of species in the two regions, the Cotteswolds would show about 60 to 65 forms and Dorset 100 to 120 or more. These numbers take no account of what may be called the 'micro-brachiopoda,' *Thecidium*, *Zellania*, etc., which, if anyone were to undertake their systematic investigation, would, I know, prove to be abundant in both regions.

Further investigation of the brachiopod-faunæ of Dorset–Somerset and the Cotteswolds shows how very little in the way of correlation can be done by a direct comparison thereof during certain particular hemeræ. Thus only three species are common to both regions in the time of the *Murchisonæ* hemera; after that there are hardly any

[1] The district south of the Mendips.

species common to both regions until the time of the *Garantianæ* hemera, when the faunæ become far more similar. These facts seem to show

(1) That about the time of the *opalini* hemera there was some check to direct communication between the Cotteswolds and Dorset–Somerset.
(2) That this check was maintained until the time of the *Garantianæ* hemera, when a known subsidence, which caused an immense overstep of deposits, allowed of free intercommunication again.
(3) That, consequently, the Cotteswold region was physically isolated, so far as any southward communication was concerned, from the *opalini* hemera until the commencement of the *Garantianæ* hemera.[1]

It will thus be understood why the Cotteswold deposits during certain hemeræ yield so many species of brachiopoda which are entirely peculiar to that region, and why, though the Cotteswolds are much nearer to Dorset–Somerset than the latter is to Normandy, there are far fewer species of brachiopods common to the two English regions than there are common to Dorset-Somerset and Normandy.

Appendix to Part III.

It was intended to offer in conjunction with Mr. J. F. Walker, F.G.S., a paper, as an appendix to the present communication, describing certain new species of brachiopoda, particularly those of the Cotteswolds; but many circumstances have contributed to delay the work. Consequently, I give the following necessary explanatory notes on certain species, hoping that our plans will be fulfilled at some other time.

1. Notes on certain Brachiopoda.

(*a*) Glossothyris.

Glossothyris Brebissoni (Deslongchamps).

1862. *Terebratula Brebissoni*, E. Desl., Bull. Soc. Linn. Normand. vol. vii. p. 321 (*teste* Deslongchamps).
1864. *Terebratula* (*Epithyris*) *curvifrons*, E. Deslongchamps, Brachiopodes, Pal. Franç. pl. xlix. p. 187.
1884. *Terebratula curvifrons*, Davidson, 'Monogr. Brit. Fossil Brachiopoda,' vol. v. Pal. Soc. App. to Suppl. pl. xx. fig. 17 only.

A dorsally (imperforate valve) sulcate, ventrally carinate Terebratuloid, the foramen somewhat small, the beak somewhat incurved.

About 12 years ago I pointed out to Dr. Davidson that the description given by Oppel, as well as the horizon which he assigned

[1] This subject was further treated by the author in 'The Relations of Dundry with the Dorset–Somerset and Cotteswold Areas during part of the Jurassic Period,' Proc. Cotteswold Nat. Field-Club, vol. ix. (1889) p. 374. To accord with present results a little alteration of zonal names is there required.

for his *Terebratula curvifrons*, did not agree at all with those of the fossil called by that name in France and England. My argument was that this shell ought not to be called '*curvifrons*'; but that, if the name were applied at all, it should be given to the shell with which the description and horizon agreed. Dr. Davidson, however, was loth to change the use of the name *curvifrons*, and preferred that the other shell should receive a new name. It was accordingly figured as *Waldheimia Haasi*, S. Buckm.—Dr. Davidson having asked that MS. names should be given to the shells for convenience of correspondence.

In restoring Deslongchamps's name of *Brebissoni* it is not my intention to alter this arrangement. There are, however, two forms known by the name '*curvifrons*' now:—one the fossil which occurs in the Oolite Marl of the Cotteswolds, the other the shell which is found south of the Mendips, and in Normandy. There are differences between the two forms in the curvature of the valves, in the shape of the beak, and the size of the foramen. It may be that they are geographical races of one species, but it is more probable that they are homœomorphous developments from a common parent. At any rate there seems to be need of distinction between the two forms; and this distinction may be readily obtained by restoring to the Paris-basin shell the name '*Brebissoni*,' which Deslongchamps was laudably ready to drop in favour of Oppel's, and by leaving the name '*curvifrons*' for the Cotteswold fossil.

That the Cotteswold shell is really Oppel's *curvifrons* is very doubtful, not only because the description given by that author does not fit the shell, but the horizon is very decidedly different; and further, the Cotteswold shell had been figured by Davidson as '*Terebratula carinata*, var.' Had Oppel wished to name this shell *curvifrons*, he would doubtless have given a reference to the figures in Davidson's work,[1] a practice which he pursued in other cases. However, this shell has been known as *curvifrons* for some time, and it may continue to enjoy that name; but the Paris-basin fossil which was originally called '*Brebissoni*' certainly ought to carry that appellation. There can be no doubt that the latter has a right to this name, but there can be very much doubt as to whether this or the Cotteswold shell have any right to be *curvifrons*. As they are two distinct forms, the present seems a desirable solution of the question.

Glossothyris curvifrons (Oppel), Davidson.

1851. *Terebratula carinata*, Davidson, 'Jur. Brach.' pl. iv. figs. 15, 16.
1854. *Terebratula carinata*, Davidson, *ibid.* App. pl. A. fig. 17.
1878. *Terebratula curvifrons*, Davidson, *ibid.* Suppl. pl. xxiv. fig. 33.

A dorsally sulcate, ventrally carinate Terebratuloid, the foramen somewhat large, the beak not much incurved. The sulcus longer, wider, and deeper than in *Brebissoni*.

Concerning the present restricted application of this name to the

[1] Davidson, 'Jurassic Brachiopoda,' pl. iv. figs. 15, 16, App. pl. A. fig. 17.

shell which occurs in the Oolite Marl of the Cotteswolds, the preceding article gives information.

It is doubtful if either this or the last shell have any right to the generic term *Glossothyris* which was proposed for the Nucleatæ, type *G. nucleata*, Sch. (sp.), but they seem to have less claim to be called *Terebratula*. They appear to be genetically related to *simplex*, J. Buckm., and *Leesi*, S. Buckm., which preceded them in time, and to *galeiformis*, M'Coy, and *provincialis*, E. E. Desl., which were their contemporaries. In fact, *provincialis* appears to be nothing more than a derivative of *Brebissoni*, while *Brebissoni* and *curvifrons* may be derivatives from *simplex*; *galeiformis* seems to be a biplicate derivative of *curvifrons*.

There is a small allied shell in the Upper Lias with a slightly sulcate imperforate valve, usually confounded with and called '*Waldheimia Lycetti*.' As it lacks the septum, however, it does not belong to the Waldheimiidæ (Magellaniidæ). It may be the parent of the whole series.

(*b*) Acanthothyris.

In the course of these investigations several species of *Acanthothyris* which are new to the Cotteswolds, and mostly new to science, have been discovered in the 'intervening beds.' In the *Witchellia*-grit there is a species not unlike a small race of *Acanthothyris paucispina*, B. and W., and a finer-ribbed form somewhat like *tenuispina*, Waagen. In the Gryphite-grit (non-gryphæiferous beds) of Stroud Hill (see p. 396) there are some specimens somewhat like *Acanthothyris Crossi*, Walker, besides a larger, more globose form. At the same horizon (Bird-in-Hand) a less globose, more coarsely costate form was found (see p. 402). At Buckholt Wood in the *Buckmani*-grit a broad, coarsely costate, rather flat species was obtained (see p. 405), and at Charlton Common in the *Buckmani*-marl (Bed 5, p. 413) was found an almost entirely globular species, with the spines in neat, regular rows, the first some little distance from the beak: altogether a most distinct form. Thus there are some six species, of which four or five are probably new. This, in a country which has received so much attention as the Cotteswolds, is a somewhat large addition to a limited group such as *Acanthothyris*.

(*c*) Rhynchonella, sp. n.

Rhynchonella cymatophora,[1] S. Buckman.

1882. *Rhynchonella gingensis*, S. Buckman, *non* Waagen, 'Brach. Inf. Ool.,' Proc. Dorset Nat. Hist. & Ant. Field-Club, vol. iv. p. 45.

1884. *Rhynchonella gingensis*, Davidson, 'Monogr. Brit. Fossil Brachiopoda,' vol. v. Pal. Soc. App. to Suppl. pl. xx. figs. 1, 1 *a*.

A *Rhynchonella* of the *tetrahedra*-type with a very gibbous dorsal (imperforate) valve, its mesial fold bearing five to six well-marked

[1] κῦμα, wave; φόρος, bearing.

ribs, and its lateral folds about seven ribs, with several smaller towards the beak-area; margin of valves on the beak-area considerably curved.

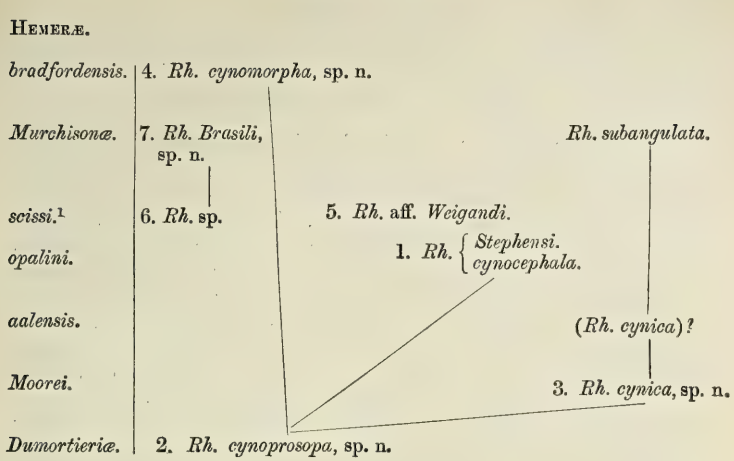
This fine *Rhynchonella* lived during the *Murchisonæ* hemera. It is a mistake to identify it with Waagen's *gingensis*, which, though a shell of somewhat similar appearance in general, is much less gibbous, especially in the imperforate valve, and has a more distinctly separated mesial fold more numerously ribbed, and is on the whole a less rotund shell. It lived several hemeræ later, and may be a descendant of the present species.

The name now given is suggested by the swelling imperforate valve. The species is excellently depicted by Davidson. It occurs at Bradford Abbas, Dorset, and is rather scarce.

(*d*) The Rhynchonella-cynocephala Group.

The top of the Oolite Marl Series (Upper Freestone) is an uncertain datum-line, owing to the different denudations to which it has been subject; yet this top has played an important part in the present paper, because between it and the Upper *Trigonia*-grit lie the 'intervening beds,' when they are present. But if this top of the Upper Freestone is an uncertain datum-line, it becomes necessary to take a palæontological datum-line. Such is afforded by a species which I have named *Rhynchonella cynomorpha*, a form occurring latest of any of the brachiopods of the Oolite Marl Series.

It has been recognized for some time that this species required distinction from *Rhynchonella cynocephala*; but before its differences therefrom could be properly stated it was necessary to know exactly what that species was. The consequence of such investigation is to find several species that have been confounded under the name *Rhynchonella cynocephala*, while that species itself was, perhaps, masquerading under another name. As the species belong to different horizons, and as they could be used for the identification of such horizons, it becomes necessary to review the whole of them. Their stratigraphical positions are shown below, as well as their generic connexion among themselves and with other fossils. The course of development is increase of plication and decrease in elevation of mesial fold. Thus the series may be traced back to *Rhynchonella acuta* of the Marlstone (Middle Lias), and forward to *Rhynchonella subangulata*. The *Rhynchonella acuta* has an uniplicate mesial fold; *Rh. cynoprosopa* and *cynocephala* have generally biplicate folds—the 1 and 3 forms rare; *Rh. cynica* has no 1-fold form, the 2 and 3 forms common, and the 4 form rare; while *Rh. subangulata* has 4, 5, and 6-plait mesial folds—the fewer-fold form, according to Mr. Upton, being geologically earlier.



Rhynchonella Stephensi, Davidson=? cynocephala (Richard). (Pl. XIV. fig. 1.)

1840. *Terebratula cynocephala*, Richard, Bull. Soc. géol. France, vol. xi. pl. iii. figs. 5 *a–d*, p. 263.
1877. *Rhynchonella Stephani*, Davidson, 'Brach. Inf. Ool.,' Proc. Dorset Nat. Hist. & Ant. Field-Club, vol. i. pl. iv. fig. 13.
1877. *Rhynchonella cynocephala*, Davidson, *ibid.* pl. iv. fig. 16.
1878. *Rhynchonella Stephensi*, Davidson, 'Monogr. Brit. Fossil Brachiopoda,' vol. iv. p. 220, Pal. Soc. Suppl. pl. xxvii. fig. 20.
1882. *Rhynchonella cynocephala*, S. Buckman, 'Brach. Inf. Ool.,' Proc. Dorset Nat. Hist. & Ant. Field-Club, vol. iv. p. 42.

A *Rhynchonella*—one of the *pugnaces*. The mesial fold narrow, fairly elevated, generally biplicate, its sides convergent.

The history of this species is worthy of particular notice. In 1877 Davidson figured a 3-plait form by the name *cynocephala*; but at the same time he depicted a young shell of the 2-plait form by the name *Rhynchonella Stephani*. In 1878 he figured the same little shell as *Rh. Stephensi*. At that time he had only a few specimens to examine; but subsequently I discovered the species in some quantity; and after an examination of the type *Stephensi*, kindly put into my hands by Davidson, I was able to convince myself that *Stephensi* was only the young of his '*Rh. cynocephala*'—an opinion set forth in my paper in 1883 (*op. cit.*). I also noticed at the time that the Dorset-Somerset specimens differed from the Cotteswold forms called '*Rh. cynocephala*,' an observation fully confirmed by subsequent collection of larger series. It then became necessary to determine which form agreed with the French fossils; because the Dorset specimens were being given the name *Stephensi* to distinguish them from the Cotteswold forms. The result showed that the Cotteswold forms required a new name, while the Dorset specimens (*Stephensi*) were really very

[1] The time when *Tmetoceras scissum* (Benecke) lived, rather later than *opalinus*, rather earlier than *Murchisonæ*.

like '*cynocephala*'; but when critically compared with the French figures, they are seen to have the mesial fold just a little shorter and less pointed; also 3–4 instead of 4–5-plait lateral folds, the excavation between these folds less pronounced, while the shell is slightly smaller altogether.[1]

This species occurs where its bed is exposed, along a line of country from Chiselborough (near Ham Hill) in Somerset to Chideock (near Bridport) in Dorset, or to Burton Bradstock—a line which runs nearly due north and south. The most notable localities are Stoke Knap, Whatley, and Middle Chinnock (near Haselbury). In the Bradford-Abbas district its horizon is not found, no strata being present; they should come between the 'Dew Bed' and the 'Paving Bed,' which, though in contact, are non-sequential.

As a typical example of this species has not been figured in the brachiopod literature of this country, an illustration of such a specimen from Stoke Knap is given in Pl. XIV. fig. 1.

The species exhibits 1- and 3-plait varieties; but these are very decidedly rare. Exact proportionate numbers of the forms would not be obtained by counting a series in a cabinet, because the 1- and 3-plait forms have been specially sought out.

Rhynchonella cynoprosopa,[2] sp. n.

1851. *Rhynchonella cynocephala*, Davidson (*non* Richard), 'Monogr. Brit. Fossil Brachiopoda,' vol. i. pt. iii. p. 77, Pal. Soc. pl. xiv. figs. 10–12.
1857. *Rhynchonella cynocephala*, Lycett, 'Cotteswold Hills,' pl. i. fig. 7 *a*, *b*.
1882. *Rhynchonella cynocephala*, Witchell, 'Geology of Stroud,' pl. i. fig. 13.

A *Rhynchonella*—one of the *pugnaces*. The mesial fold narrow, very considerably elevated, generally biplicate, with its side-margins nearly parallel.

This species is excellently figured by Davidson, and it has passed under the name of *cynocephala*. If, however, his figures be compared with those given in the 'Bulletin' of the Geological Society of France,[3] particular differences may be noted. In the first place, the mesial fold is very much more elevated, and it is so turned over the beak that a line from the tip of the mesial fold to the beak will be nearly at right angles with a line from the beak to the edge of the lateral fold of the perforate valve—a character well shown in Davidson's fig. 11 *b*, which should be compared with the French fig. 5 *a* held in the same position. Then, in the second place, the mesial fold is of a more uniform breadth, so that its side-margins, in an anterior view of the perforate valve, are more nearly parallel—features particularly brought out in the drawings by Davidson, Lycett, and Witchell. Thus the two points of the end of the mesial fold are not only farther apart, but separated by a wider notch.

[1] Since the above was written, a species even more like the French form has been found by myself at Withington in the Cotteswolds, in the sandy ferruginous beds (*scissi* hemera), so that I have much hesitation in saying that *Stephensi* is a synonym of *cynocephala*.

[2] κυνοπρόσωπος, dog-faced.

[3] See preceding article, p. 449.

Lastly, the lateral folds are more curved in the opposite direction to the mesial fold, so that the mesial fold is longer; there is a concave curve between the rostrate part of the perforate valve and the edge of the lateral fold, and the shell becomes altogether more angular.

These characters are borne out not only by the figures of the authors mentioned, but by a large series of specimens in my cabinet. They vary, of course; for instance, in the prominence of the mesial fold and its liability to be rectangular to the lateral fold, as noted above; but no specimens of a considerable series of the preceding species attained to anything like rectangularity. Thus, while lines from the beak to the lateral and mesial folds over the respective valves may give in this species an angle of about 87°, no specimens of the preceding species show more than about 65°.

Rh. cynoprosopa occurs in the Cephalopoda-bed of the Cotteswolds; and it lived during the *Dumortieriæ* hemera. It is found at Haresfield Hill and Standish Beacon—plentifully, but of rather small size, in a bed of brown earthy marl, larger but scarcer lower down, with *Terebratula haresfieldensis*; also at Standish Park, at Coaley Peak, and other localities. Like the last species, it shows 1- and 3-plait varieties, but these are very rare; the 2-plait form greatly preponderates.

Rhynchonella cynica,[1] sp. n.

1882. *Rhynchonella Beneckei*, S. Buckman (*non* Haas), 'Brach. Inf. Ool.,' Proc. Dorset Nat. Hist. & Ant. Field-Club, vol. iv. p. 51.
1884. *Rhynchonella Beneckei*, Davidson, App. to Suppl. 'Monogr. Brit. Fossil Brachiopoda,' vol. v. pl. xx. figs. 8–10, Pal. Soc.
Rhynchonella cynocephala, auct.

A *Rhynchonella* somewhat like *cynocephala*. The mesial fold broad, not much elevated, bi- or triplicate, sometimes quadriplicate.

I cannot defend my identification of this species with the *Rh. Beneckei*, Haas & Petri[2]—an identification considered by Davidson as very uncertain (*op. cit.* p. 274), although he figured it by that name. It therefore becomes necessary to give it a new designation.

The present species is not unlike a somewhat large edition of *Rh. cynocephala*, though it differs—not only in being always of much larger size, but in the greater coarseness of its ribbing, as well as in the broader, more deeply and broadly-divided mesial fold. From *Rh. cynoprosopa* the coarser ribs, the broader and much less elevated mesial fold easily separate it.

The number of ribs on the mesial fold is variable, but in this respect the present species differs from *Rh. Stephensi* or *Rh. cynoprosopa*. Those species show a great preponderance of forms with 2 plaits on the fold, rarely forms with 1 and 3 plaits. The present species shows mostly forms with 2 and 3 plaits, rarely varieties with

[1] κυνικός, dog-like.
[2] A correction in the text altered the name to *Rh. delmensis*, H. & P.

4 plaits, and none, so far, with 1 plait. The percentage of a series is roughly thus: with 2 plaits 54·5, with 3 plaits 35·5, with 4 plaits 10·0.

Rhynchonella cynica occurs chiefly in the Yeovil Sands around Bradford Abbas, in the hard sand-burrs, so that its extraction uninjured is rare; it is also occasionally found in the 'Dew Bed' at Bradford Abbas; it is rarely met with at Ham Hill in the stone-beds, but as they are composed of broken shells it may have lived there abundantly; it also occurs in the Northampton Sands in the neighbourhood of Northampton,[1] where it is known as *Rh. cynocephala*, and specimens (differing from typical *cynoprosopa* in want of elevation of the mesial fold, and not unlike *cynica*) occur in *Moorei*, and, I think, *aalensis*-beds of Coaley Peak and Penn Wood: they have been confounded with *Rh. cynocephala* (*cynoprosopa*) and consequently somewhat overlooked; but they are to a certain extent intermediate between *cynoprosopa* and *cynica*.

The Dorset specimens of *Rh. cynica* lived at a later date than the Cotteswold species, *Rh. cynoprosopa*, namely, in the *Moorei* hemera. The Northampton specimens come from beds deposited at about the same time (*Moorei*) or a little later—later at any rate than the beds containing *cynoprosopa*; and *cynoprosopa* is not known in Dorset.

As the type of *Rh. cynica* I take the specimen with two plaits on the mesial fold—this being rather the commoner form—represented by Davidson, App. to Suppl. pl. xx. fig. 8.

Rhynchonella cynomorpha, sp. n. (Pl. XIV. figs. 2–4.)

1882. *Rhynchonella cynocephala*, var., Witchell, 'Geology of Stroud.' p. 47.
1887. *Rhynchonella cynocephala*, var., S. Buckman, 'Inf. Ool. betw. Andoversford, etc.,' Proc. Cotteswold Nat. Field-Club, vol. ix. p. 115.

A *Rhynchonella* like *Stephensi* or *cynoprosopa*, but always much smaller, and differing in the greater number of plaits on the lateral folds. The mesial fold has somewhat parallel sides, like *cynoprosopa*, but more curved longitudinally in respect of the ventral valve.

This species is, in general characters, like *Rh. Stephensi* and *Rh. cynoprosopa*, but it never attains to the size of either of them. It is more like the latter, in that the mesial fold is well elevated, the angle with a line from the beak to the lateral fold being about 70°; also the mesial fold is of fairly uniform width. It differs from *Rh. cynoprosopa* by its smaller size, by the greater number of ribs on the lateral folds, by greater gibbosity of these folds in both valves, and by somewhat greater curvature of the mesial fold of the perforate valve. From *Rh. cynocephala* it differs by its more raised mesial fold of more uniform width, from *Rh. Stephensi* by the same character, by the greater number of ribs on the lateral folds, and by all ribs beginning nearer to the beak and umbo.

The species varies as to the number of plaits on the mesial fold, but the 2-plait form is most frequently found. Out of a series

[1] Sent by Mr. B. Thompson, F.G.S.

collected, good and bad, for the purpose of noting the percentage of different plaited forms, the following results were obtained:— 1 plait, 15; 2 plaits, 63; 3 plaits, 22 per cent.

Though *Rh. cynomorpha* occurs in the Cotteswolds about 100 or more feet above *Rh. cynoprosopa*, it is most probably the descendant of that species, and has had nothing to do with *Rh. cynocephala* or *Rh. cynica*.

This species is essentially a Gloucestershire fossil, and it seems to be of very restricted geographical occurrence. It is plentiful at the Frith Quarry, near Stroud; it also occurs at Scotesquar, on the other side of the Painswick valley, at Notgrove Station at the other side of the county, always high up in the Oolite Marl series (see p. 459), and at Cranham Wood, near Birdlip.

Rhynchonella aff. Weigandi, Haas & Petri. (Pl. XIV. fig. 5.)

1882. *Rhynchonella Weigandi*, Haas & Petri, 'Brach. d. Juraf. Elsass-Lothringen,' Abh. z. geol. Spez.-Karte v. Elsass-Lothringen, vol. ii. pt. ii. pl. v. figs. 13 *a–c*.
1882. *Rhynchonella cynocephala*, var., S. Buckman, 'Inf. Ool. Brach.,' Proc. Dorset Nat. Hist. & Ant. Field-Club, vol. iv. p. 42.

A globular *Rhynchonella* of the *cynocephala*-type, with uniplicate mesial fold not much elevated.

In the reference given above, I remarked that a 1-plait variety of *Rh. cynocephala* (*Stephensi*) occurred at Drimpton itself, not in conjunction with the other forms. They are more globular little fossils than the 1-plait forms of *Stephensi*, and are very like the above-quoted figures of *Rh. Weigandi*, except in having a more elevated mesial fold and less conspicuous lateral ribs. They are rare; I have them from Drimpton and from Netherton in Dorset, from the base of what is known as 'Inferior Oolite limestone:' that is, beds deposited rather before the *Murchisonæ* hemera strictly so-called.

Rhynchonella, sp. (Pl. XIV. fig. 6.)

A globular *Rhynchonella* of the *cynocephala*-type, with biplicate, somewhat elevated, but not well separated mesial fold.

Two specimens in my collection from Middle Chinnock, near Haselbury, Somerset, differ decidedly from *Rh. Stephensi* in their globose rounder form and less separated mesial fold. They may be 2-plait forms of the species mentioned above (*Rh.* aff. *Weigandi*); but it is uncertain whether they did not live a little earlier.

Rhynchonella Brasili, sp. n. (Pl. XIV. fig. 7.)

A small, circular, depressed shell of the *cynocephala*-type, with obscure, not elevated, 2-plait mesial fold.

The depressed form, and the want of elevation of the mesial fold, separate this shell distinctly from any of the foregoing. It occurs at Corton Downs, Somerset, and lived during the *Murchisonæ* or, less probably, *bradfordensis* hemera. As a specimen of the same

species has been sent to me by M. Louis Brasil, of the Faculté des Sciences, Caen, from "'*Murchisonæ*,' May (Calvados)," without name, I have much pleasure in dedicating this species to him.

(*e*) Terebratula Buckmani and T. Buckmaniana.

In the sections described in this paper the above names have occurred with very considerable frequency. As to *T. Buckmani* there can be no doubt—it is the elliptical, barely uniplicate form; but the term '*Buckmaniana*' was originally given as a varietal name to three or four distinct forms which appeared to be 'varieties' of *Buckmani*; and in general usage the name has been extended to include even other biplicate *Buckmani*-like fossils than those figured by Davidson.[1] Therefore, in the foregoing sections, the term '*Terebratula Buckmaniana*' should be interpreted 'biplicate forms of the *Buckmani*-type.'

When, however, a critical examination of these biplicate forms is undertaken, and they are compared with the original figures of *Buckmaniana*, it is found that they really do not agree with any of them. Davidson's fig. 14 (Suppl. pl. xix.) is, by the explanation of the plate, presumably from the same horizon, but neither in Mr. Upton's cabinet nor my own are there any specimens of this size sufficiently distinguished by biplications from *Buckmani*, nor anything much like it, except some small specimens. Of the remaining forms, figs. 15, 16, 17, Mr. Upton expresses the opinion, and I think it has considerable justification, that fig. 16 is one of the *globata*-series, and therefore from an altogether different horizon. There remains, then, the form or forms depicted in figs. 15 and 17: these are well-known fossils from a particular bed of Cleeve Hill, and are well represented. But none of the biplicate *Buckmani*-like fossils found in the *Buckmani*-grit of the Mid-Cotteswolds—none of the forms to which the term '*Buckmaniana*' has been given in this paper—agree exactly with these shells; and, curiously enough, at Cleeve Hill they are not found associated with the true *Terebratula Buckmani*.

The date of the deposit in which they are found—that is, its contemporaneity with the *Buckmani*-grit—is certainly very far from being proved.[2] But, however this may be, it seems as if it would be necessary, in order to prevent confusion, to restrict the term '*Terebratula Buckmaniana*' to this Cleeve-Hill form, and to replace it in the foregoing sections by the phrase 'biplicate derivatives or connexions of *Buckmani*, usually called *Buckmaniana*.' To two of these, figured by Davidson under entirely different names, there is now a suitable opportunity for giving distinct appellations.

[1] 'Monogr. Brit. Fossil Brachiopoda,' vol. iv. (1882) Pal. Soc. Suppl. pl. xix. figs. 14–17.

[2] But see Postscript, p. 461.

TEREBRATULA CRICKLEYENSIS, sp. n. (Pl. XIV. fig. 8.)

1878. *Terebratula perovalis*, var. *Kleinii*, Davidson (*non* Lamarck), 'Monogr. Brit. Fossil Brachiopoda,' vol. iv. Pal. Soc. Suppl. pl. xvii. figs. 9, 9 *a*.

This is a biplicate form which occurs in the same bed with *Terebratula Buckmani*. The frontal folds are close together, fairly elevated, and not conspicuously separated. The side-margin is fairly curved. The valves are somewhat regularly convex, transversely, the perforate one, however, being slightly carinate. In many specimens the margins of the valves are thickened, as in the example depicted by Davidson—a sign of old age.

This shell is not the *Kleinii* of Lamarck, which is a much broader fossil with more prominent folds. It has been more usually, perhaps, linked with *Phillipsiana*, notwithstanding that Davidson separated it therefrom. It is not unlike a dwarf *Phillipsiana* in general aspect, but it is easily distinguished. It is broader and less elongate, generally more so than in Davidson's figures; the frontal folds are much closer together, more elevated, and less separated from one another by any sulcus in the imperforate valve. It has also been called '*Buckmaniana*'; but if that name be restricted to the subcylindrical Cleeve Hill fossil, there is no difficulty in distinguishing this rather flattened, subpentagonal shell therefrom.

T. crickleyensis occurs at Charlton Common and at Tuffley's (Crickley) in exactly the same bed with *Terebratula Buckmani*. It has also been found at other localities.

TEREBRATULA UPTONI, sp. n.

1878. *Terebratula perovalis*, Davidson (*non* Sowerby), 'Monogr. Brit. Fossil Brachiopoda,' vol. iv. Pal. Soc. Suppl. pl. xviii. fig. 11. Type-form; fig. 10 narrower, more aged variety (figs. 12, 13, young?).

Allusion has been made in this paper to a form under the name '*Terebratula* aff. *Buckmaniana*, broad form.' The need of a name seems to be felt by other people besides myself; and I consequently dedicate this species to my friend Mr. C. Upton.

In its most typical form the shell is nearly circular, with a broadly, feebly biplicate front-margin, and valves which are rather flat. Davidson called it *perovalis*; but it is less biplicate and too circular. It is closely allied, genetically, to *Buckmani*; but it is presumably a derivative of a more circular form—such would in fact be the parent of *Buckmani* too.

Terebratula Uptoni occurs nearly at the top of the *Buckmani*-grit at Charlton Common—its horizon appears to be about 2 feet below the Gryphite-grit, or 7 feet below the Notgrove Freestone, and it is not uncommon. It is, therefore, some little way above *Buckmani*.

Davidson's fig. 11 is a typical form; fig. 10 shows signs of old age; figs. 12 and 13 are presumably young forms of a somewhat narrow shell, but no side view is given.

Genetic observations on brachiopoda indicate that biplicate *Terebratulæ* are, at any rate in the Jurassic rocks, independent, or heterogenetic, homœomorphous derivatives of non-plicate forms. The method of nomenclature hitherto adopted rather tends, however, to confuse these biplicate forms together, either as the same species, or as varieties of one another—and they are often difficult to distinguish—and totally overlooks their relationship to the non-plicate forms (from which they appear easily separable), thus ignoring their genetic affinities altogether. A case in point is Davidson's confusion of what is now named *Uptoni* with *Terebratula perovalis*; and another is the inclusion of *T. Phillipsiana* as a variety of the later-appearing *T. Phillipsi*; and, again, the placing of *T. submaxillata* as the same species, or as a variety, of the much later *T. maxillata*. A primary objection may be taken, that a variety cannot live before the species of which it is supposed to be a variety came into being—especially in a case where it is about 2 'ages' earlier; and particularly when there are either no links between the forms, or only casual, isolated examples—apparent but not real links—homœomorphous but not homogenetic forms.

Really the course of development was this: there was a non-plicate stock with a tendency to throw off a constant series of plicate, and consequently more or less homœomorphous, derivatives. The first stage was a circular form; the second an elongate form, both non-plicate, or the latter feebly uniplicate; the third an uniplicate or incipiently biplicate form; the fourth a pronounced biplicate form; the fifth a reversion to an uniplicate form, with pronounced raised fold. Or the second stage may be omitted, and the circular form may be retained, becoming directly plicate; or the second form may be directly multiplicate—a development of the non-plicate first form—as in *Terebratula fimbria*.

Taking the *punctata*-stock, there is, first, in the Middle Lias, the circular form, *Jauberti*, with derivatives—the thin, elliptical *punctata*, the subcylindrical *subpunctata*, and the globose *Edwardsi*. Later (*Dumortieriæ* hemera) appears *haresfieldensis*, called by Davidson a variety of *punctata*, but really a mutation of a *punctata*-like form; and this becomes a starting-point for a series of new developments: it breaks up into varieties, pointing, apparently, to *Terebratula perovalis* (*Murchisonæ* hemera) as a development in one direction [1]; while *Terebratula ampla*, J. Buckm., shows the persistence of the circular form. Thus *ampla*, usually called a 'variety of *perovalis*,' is, biologically, a less modified form, is nearer to the original stock, and presumably had a somewhat different origin from that of *perovalis*. Then, somewhat later than *haresfieldensis*, namely, in the *opalini* hemera, lived a rather more circular form with acute margins, for which no name has yet been discovered; but the form is found at Frocester (Gloucestershire), Chiselborough

[1] Perhaps through *T. trilineata*; but the date of that fossil has not been recorded with sufficient accuracy for the present purpose.

(Somerset), and Stoke Knap (Dorset). Then later, in the *discitæ* hemera, appears *cortonensis*, a feebly uniplicate derivative from a *punctata*-like form, itself developing biplicate derivatives not unlike the young of the earlier species *perovalis*. Contemporaneously in the Cotteswolds appears the more-regularly elliptical *Buckmani*, developing into various biplicate forms, for instance, the associated *T. crickleyensis*; and then there is the more circular, feebly biplicate *Uptoni*—a development from a more circular form than *Buckmani*. Later (*Sauzei* hemera, Sandford Lane) is the more-inflated-than-*Buckmani*, uniplicate *ventricosa*, which, according to Deslongchamps's figures ('*submaxillata*'), appears to develop in many ways (biplicate). Then there is *Phillipsiana*, of somewhat uncertain exact date—a biplicate derivative from a *Buckmani*-like form; and in the *Humphriesiani* hemera of Dorset are forms called *Buckmani* (uniplicate) and *Buckmaniana* (biplicate)—both somewhat different from the earlier Cotteswold fossils which bear those names.

Then, though the exact date of *Phillipsiana* is undetermined,[1] it certainly lived much earlier than *Phillipsi*. The genesis of that fossil was, first *gravida*, a tumid, short form, a possible derivative from the *punctata*-stock; next *Craneæ*, an elongate form; next *Dolhae*, feebly biplicate; next *Phillipsi*, strongly biplicate. Its contemporary *Stephani* (biplicate) came by another and different route as a development of some *ventricosa*-like form; and a possible development of *Stephani*, the *T. linguifera* of the Fullers' Earth Rock, shows the return to the uniplicate form, with raised fold.

Here may be noticed the case of *T. submaxillata* and *T. maxillata*; the former is sometimes merged in the same name as the latter, and then *T. maxillata* is said to range from the base of the Inferior Oolite into the Cornbrash—an absolutely incorrect statement; because in many hemeræ no maxillatoid forms were in existence.

T. submaxillata occurs in the Oolite Marl (*bradfordensis* hemera), and unless it be the biplicate development of the uniplicate *T. Whitakeri*, its descent is rather uncertain. Then there were no maxillatoid forms for a considerable time—not until the *Clypeus*-grit is reached (post-*Garantianæ* hemera), when certain biplicate, almost quadriplicate forms make their appearance. Then some time elapsed before the true *T. maxillata* came. It is in no way a descendant of *T. submaxillata*, or of the maxillatoid forms of the *Clypeus*-grit, for the former, at any rate, shows greater senility; but it is, as its own young indicate, a biplicate development of the non-plicate *T. marmorea*, Oppel; and it is only in the Cornbrash that *maxillata* seems to develop senile forms.

Analogous cases of the heterogenetic development of similar but entirely unrelated forms are well known among ammonites. Mojsisovics has called such cases, between non-contemporaneous ammonites, 'heterochronous convergence.'[2] I would rather apply

[1] See Postscript, p. 461.

[2] 'Ceph. d. Hallstätter Kalke,' vol. ii. Abhandl. d. k. k. geol. Reichsanstalt, vol. vi. pt. ii. (1893) p. 5.

the term 'heterochronous homœomorphy' to the phenomenon[1]; and the term 'isochronous homœomorphy' would describe the resemblance between the contemporaneous *Buckmani* with its derivatives, and *cortonensis* with its developments. These are species geographically isolated; but isochronous homœomorphy would be applicable to the likeness between heterogenetic species of similar geographical range—for instance, *T. Stephani* and *T. Phillipsi*. Again, in the case of the Cotteswold forms, *T. plicata* and *T. fimbria*, both heterochronous and isochronous homœomorphy are in evidence. Thus these two species are not descended one from the other; but they are heterogenetic multiplicate derivatives from a non-plicate circular form. Elongation and subsequent acquirement of folds produces *T. plicata*, a common fossil of the Pea-grit (*Murchisonæ* hemera), where the circular form also acquires plications (*T. fimbria*), but is rarely met with. Later, in the Oolite Marl (*bradfordensis* hemera), the circular plicate form (*T. fimbria*) is common; and it shows a tendency to elongation with excessive plication at a still later date (Upper Freestone); while, somewhat before *T. fimbria* became common, the elongate, plicate form (*T. plicata*) dies out, in the early part of the Oolite Marl, where are found a few modified (aged) descendants of the true *plicata* of the Pea-grit.

These remarks will show the kind of revision which the Jurassic brachiopoda require, in order that their genetic affinities may be understood, and also that specific names may be properly applied so as to enable such genetic affinities to be expressed. They also indicate the reason for the present application of certain new specific names.

2. The Oolite Marl Series and its Brachiopod-sequence.

This includes the 'Oolite Marl' and the 'Upper Freestone.' It is obvious to those who work in the Cotteswolds that these terms are purely arbitrary; because marly conditions prevailed at one locality contemporaneously with freestone conditions at another. A good exposure of the series may show very little freestone at all, but much marl; and it may be all the more welcome to the geologist. Such is the exposure at the Frith (p. 399): this is one of the finest and most prolific in the Cotteswolds; its rival is that shown in the railway-cutting at Notgrove Station, distant $16\frac{1}{4}$ miles N.E. by E. The upper beds of the series are more prolific at the Frith, and the lower beds at Notgrove Station. I gave a section of the latter locality in Proc. Cotteswold Nat. Field-Club, vol. ix. pt. ii. (1887) p. 114[2]; and the Frith section may be advantageously compared therewith. It will be seen that at the Frith there is 19 feet 9 inches of strata in the Oolite Marl series above the *Rh. subobsoleta*-horizon,

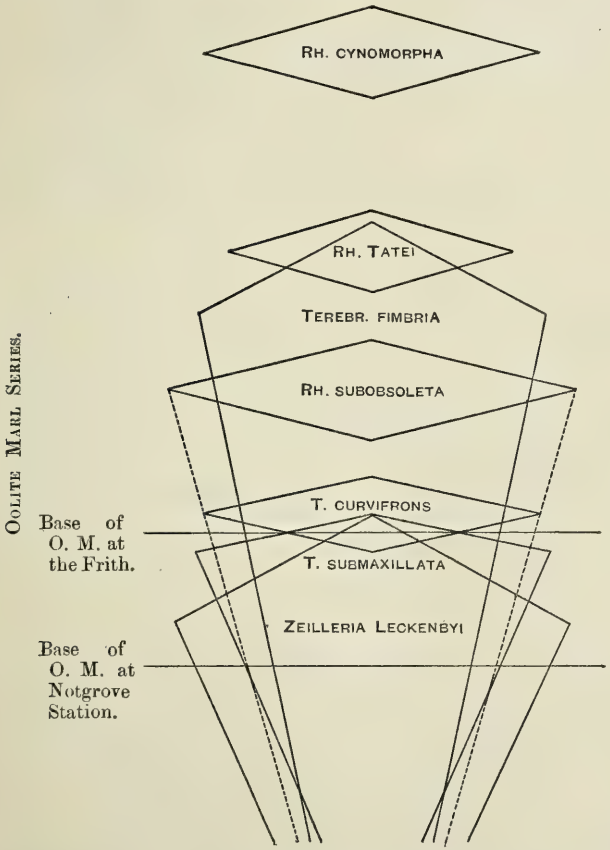
[1] It might arise from divergence; and this term proposed does not commit us to the means whereby the result is obtained, it only describes the effect produced.

[2] Of Bed 21 of that section 9 lbs. yielded 563 specimens, excluding micromorphs; they were mostly brachiopoda. Many were crushed.

and that there is practically nothing below it; while at Notgrove Station there is 18 feet 1 inch of rock above this horizon, and 14 feet 9 inches below it. This at any rate explains why Notgrove is the more prolific below.

Table VIII.

Diagrammatic Table to show the sequence in the acmes of development of various species of brachiopoda—the greatest divergence in the lines indicating the acme in each case.



Note.—*Terebratula fimbria* and *Zeilleria Leckenbyi* are found in the Pea-grit of the Stroud district; and *T. fimbria*, in its aged form, probably ascends higher than is shown here. The development would be more correctly represented by curved lines, but at present the data collected are not sufficient.

From further comparison of these sections it will be seen that the succession of the brachiopod-faunæ corresponds exactly. At neither locality is there any lithological deposit similar to the Upper Free-

stone as usually known; but it is probable that in both cases the Upper Freestone is represented by the upper beds of the series—it is, in fact, a case of a marly condition of the Upper Freestone in each locality. Though lithologically there is often no reason for distinguishing between Oolite Marl and Upper Freestone, yet it may be noted that palæontologically five brachiopod-horizons can be distinguished, and that these are independent of the lithology. Thus there is the following sequence:—

1. *Rhynchonella cynomorpha*, sp. n.
2. *Rhynchonella Tatei*, Dav.
3. *Terebratula fimbria*, Sow., at its acme, and *Rhynchonella subobsoleta*, Dav., rather below it.
4. *Terebratula curvifrons*, Oppel, and *T. submaxillata*, Dav.
5. *Zeilleria Leckenbyi* (Walker), at its acme.

Of the above the two later horizons, Nos. 1, 2, may be taken to indicate Upper Freestone or its equivalent, the three earlier Nos. 3, 4, 5, the true Oolite Marl. Table VIII. (p. 459) shows roughly the sequential development of certain brachiopoda generalized.

Summary and Conclusions.

The following are the facts and conclusions advanced in this paper:—

1. A record of the stratigraphical sequence of the 'intervening beds' between Stroud and Leckhampton.
2. The correlation of the Gryphite- and Lower *Trigonia*-grits respectively.
3. A demonstration of how the stratigraphical sequence has been affected by the 'Bajocian denudation.'
4. The discovery of the importance of the Cold Comfort section, and the position of its beds.
5. The discovery of a new ammonitiferous horizon in the Cotteswolds.
6. The bearing of this discovery on Jurassic chronology.
7. Correlation of the 'intervening beds' with Dorset strata, and the necessity of dividing the '*Witchellicæ* hemera' into this and '*Sonniniæ* hemera.'
8. The geographical extent of the 'intervening beds'; and a demonstration that the strata of the *Witchellicæ* hemera only cover about $1\frac{1}{2}$ square miles in the Mid-Cotteswolds.
9. Records of the chronological sequence of brachiopoda; with special reference to their value in stratigraphical correlation.
10. Description of certain new brachiopoda, particularly noticeable for their value as indicators of horizons.
11. Notes on the development of certain brachiopoda, to show the importance to nomenclature of exactness in recording horizons, and the importance to correlation of having a nomenclature in accordance with development, by avoiding a confusion of heterogenetic forms.

Postscript.

[A few weeks after this paper was read I was able to satisfy myself that I had found the clue to the mystery of the ragstone-beds of Cleeve Hill, which has been a difficulty for a very long time. As their sequence affects the date of *Terebratula Phillipsiana*, mentioned in this paper (p. 457), the following note of the succession may be made:—

0. Upper *Trigonia*-grit.
1. Sandy beds with *Terebratula Phillipsiana* and *T. Buckmaniana*—a bored bed at the top.
2. Massive limestones, with numerous casts of *Bourguetia* aff. *striata*, Sowerby, and many lamellibranchs.

(1 & 2: about 20 feet thick.)

3. Limestone with *Acanthothyris* aff. *paucispina*, Buckm. & Walker, probably equivalent to the *Witchellia*-grit of Cold Comfort; *Terebratula Wrighti* being 1½ feet from the base (see p. 417).
4. Notgrove Freestone.
5. Gryphite-grit.
6. Beds with *T. Buckmani* partly exposed.
7. Lower *Trigonia*-grit, partly exposed.
8. Blue clay resting on yellow and white siliceous sands=Harford Sands.

Nos. 1 to 8 are the 'intervening beds.' The interest lies in Nos. 1 & 2, which are superior to the *Witchellia*-grit, and are not matched by any strata described in this paper. They help to fill the gap between the *Witchellia* and Upper *Trigonia*-grits (see p. 422), and yet the latter is still a non-sequential deposit.

In the Table of Brachiopoda, No. VII., pp. 440–443, the following alteration has been made, as suggested by the above sequence of strata: namely, the placing of the *Phillipsiana*-beds with the fossils they yield, above the *Witchellia*-grit, suggesting that *T. Phillipsiana* and *T. Buckmaniana*, *sensu stricto*, probably lived during the *Sauzei* hemera as contemporaries of the Dorset and Continental *T. ventricosa*. This and the detailed stratigraphical work on Cleeve Hill will receive future attention.

One other point may be noticed. In Oolite rocks the matrix differs so much and so frequently in a slight vertical range that spoil-heap specimens and fossils collected many years ago, without exact indication of horizon, may often be of considerable service. Again, in shallow quarries one or two beds may be fossiliferous, the rest unfossiliferous, giving presumptive evidence of horizon for a specimen from the locality. These remarks have reference not only to specimens alluded to in this paper, but also to the fact that Wright obtained several ammonites from Cleeve Hill; and if these could be traced and inspected their horizons might not only be ascertained from lithological characters, but they would give valuable evidence for the exact correlation of the Cleeve Hill beds with Dorset.—April 15th, 1895.]

EXPLANATION OF PLATE XIV.

Fig. 1. *Rhynchonella Stephensi*, Davidson=?*cynocephala*, Richard. From Stoke Knap, near Broad Windsor, Dorset. *Opalini* hemera (p. 449).

Figs. 2–4. *Rhynchonella cynomorpha*, S. Buckman. Fig. 2. Form with 2-plait mesial fold. 2*a* enlarged, twice natural size. Fig. 3. Form with 1-plait mesial fold. Fig. 4. Form with 3-plait fold. Frith Quarry, Painswick, Gloucestershire. Upper part of Oolite Marl series. *Bradfordensis* hemera (p. 452).

Fig. 5. *Rhynchonella* aff. *Weigandi*, Haas & Petri. From Netherton, near Beaminster, Dorset. *Opalini* hemera (p. 453).

Fig. 6. *Rhynchonella* sp. From Middle Chinnock, Somerset. *Opalini* hemera (p. 453).

Fig. 7. *Rhynchonella Brasili*, sp. n. From Corton Downs, Somerset. *Murchisonæ* or perhaps *bradfordensis* hemera (p. 453).

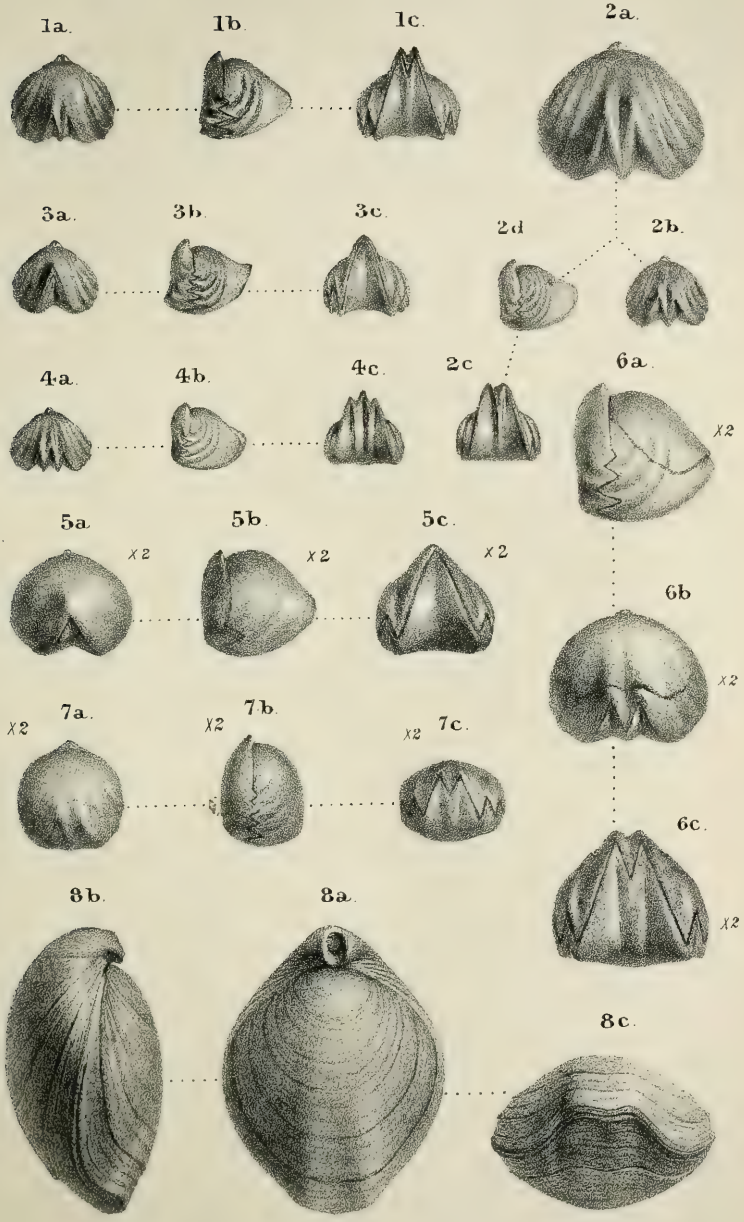
Fig. 8. *Terebratula crickleyensis*, S. Buckman. From marl-bed of the *Buckmani*-grit, near Air Balloon, Crickley, Gloucestershire (Tuffley's Quarry, Section xvi. Bed No. 5, p. 409). Post-*discitæ* hemera (p. 455).

Discussion.

The President expressed his regret at the absence of the Author, and his thanks to the Secretary, Mr. Teall, for the excellent summary that he had given of a very large and important paper containing a great amount of valuable and detailed information on the Mid-Cotteswold area. The Author gave a careful record of a large number of sections, showing the succession of the beds, and illustrating his views on the 'Bajocian denudation,' which could be followed with interest by all his hearers; but when he entered upon the question of the ammonite-fauna, he used so technical a nomenclature that only those who had learnt its significance in detail could readily follow his views.

Mr. H. B. Woodward complimented the Author on his careful detailed work, and said that he differed from him mainly on matters of nomenclature, and not with regard to the general succession of the strata and their fossils. Months upon months of labour in each quarry would, however, be necessary to test the value of the minute divisions made by Mr. Buckman. Without such prolonged work one could not tell how the distribution of fossils might vary in each layer of rock, and he would hesitate to regard the absence of any hemeræ as indicative of a break in the series of strata.

The Rev. H. H. Winwood also spoke.



F.H. Michael del. et lith.

Mintern Bros. imp.

JURASSIC BRACHIOPODA.

30. *The* PHYSICAL FEATURES *and* GEOLOGY *of* MAURITIUS. By Major H. DE HAGA HAIG, R.E., F.G.S. (Read April 3rd, 1895.)

[Abridged.]

[PLATE XV.—MAP.]

I. PHYSICAL FEATURES.

THE Island of Mauritius is the centre of a line of three—Réunion, Mauritius, and Rodriguez—some hundreds of miles apart; they are all volcanic, and in reality quite unconnected, except in so far as they are on a line of volcanic action. Mauritius is about 40 miles long and 27 miles broad, and it consists essentially of a mass of volcanic débris thrown up from craters now extinct. A central ridge, which is the main watershed of the island, and in which are situated all the more recent craters, commences at the south, where it has an elevation of about 2000 feet, and runs northwards, gradually curving to north-east. The gentle slopes on each side are stopped, round the greater part of the circumference, by ranges of mountains up to nearly 3000 feet in height, so thin and steep as to resemble walls. From the outer precipices of these, comparatively level plains of variable width stretch to the sea. There are three wide gaps in these mountains, through which the slopes from the main watershed fall gently to the sea. The northern part of the island—the pointed end of the pear—is cut off from the rest by these mountain-walls, but the general direction of the watershed continues across it at a much lower level, and is even prolonged under water by a bank extending 14 or 15 miles before it sinks to 100 fathoms below the sea: the general depth of the sea-bottom around being about 1800 fathoms. The five or six small islands to the north are on this bank, which also rises in some places in the objectionable form of dangerous reefs, on which a furious surf is always breaking. There is also a bank,[1] extending from the south-western point of Mauritius (10 miles) towards Bourbon, which appears to be a continuation of the central ridge. In fact, Mauritius is on a line of weakness of the earth's surface, along which volcanic disturbances have taken place. This line passes through the volcanic islands of Rodriguez, Bourbon, and Madagascar. From soundings taken round Mauritius and Bourbon, in connexion with a scheme for laying a submarine telegraph-cable, it was found that between the two there was a level sandy plain at a depth of 1800 fathoms, which extended all round Mauritius, except to the north, where, as one of the men employed on the work stated, 'It was like sounding over precipices; depths of 600 and 1300 fathoms would often occur in close consecutive soundings.' It has often been supposed that the Mascarene Islands were at one time united,

[1] Called 'l'Ilot aux Pintades.'

because their flora and fauna have so much in common and distinct from what is found elsewhere, but the results of these soundings do not lend any support to the theory.

The mountains of Mauritius consist of superimposed lava-flows, generally with burnt volcanic ash between the layers. They are very precipitous, especially on the seaward side, though they nowhere reach the coast. The most peculiar of them is the well-known 'Pieter Both;' this is a wall-like mass, culminating in a triangular pyramid, surmounted by a huge block of lava which has the shape of a pegtop standing on its point. From every point of view this curious mountain resembles something different: now it is an old woman wrapped in a shawl, then a most striking standing statue of the Queen with long train and a regal air. From another spot it is an immense, meagre, sitting figure, resting its feet on a footstool. Another strange rocky mountain is the 'Corps de Garde,' so called from its extraordinarily exact profile in high relief of a recumbent figure of a man in the uniform of the old French Guard, with high boots, three-cornered hat, and arms folded. The figure from another point of view resembles a bust of King Louis Philippe, with an immense shirt-ruffle and a wig.

Isolated hills ending in a conical shaft of rock occur in many parts of the island, and are no doubt the remains of the central cores of ancient volcanos. There are a number of very perfect craters, most of which are still clothed with dense forest, and some few enclosed lakes, the best known of which are the 'Grand Bassin,' the 'Bassin Blanc,' and the 'Trou aux Cerfs.'

The neighbouring island of Bourbon still contains an active volcano, whose eruptions are of frequent occurrence, and it seems probable that both islands are on the same line of action of the subterranean force which has thrown them up. So we may regard this active crater as the safety-valve which prevents the doubtless diminished subterranean heat from venting itself on Mauritius. Were the Bourbon volcano to become choked from any cause, there might be danger to the sister isle. It is evident that the volcanic fires beneath Mauritius are merely dormant, not extinct, for they have several times manifested themselves by earthquakes, for example on May 15th, 1854, August 24th, 1860, and January 6th, 1863. These shocks, however, were very slight, else they would have shaken off the Pieter Both's balanced knob.

The elevation of the central ridge of Mauritius causes the moisture-laden south-easterly trade winds, which blow over it during nine months of the year, to rise; consequently their temperature is reduced, their moisture is precipitated, clouds are thus formed, and a very heavy rainfall ensues. This, combined with the steepness of the river-beds, sometimes so great as 1 in 15, causes the cutting force of the streams to be very powerful. They have dug out for themselves immense ravines: that through which the Tamarin river runs is 1160 feet in depth, while the Black River gorges are upwards of 2000 feet deep, and there are few

streams that at some part of their courses have not cut gullies several hundred feet deep. It is often said that these ravines are fissures caused by volcanic action, but in that case the beds of hard lava which stretch across them, causing magnificent waterfalls, would not have been left uncracked. These river-gullies are a great feature of Mauritian scenery; their sides are so precipitous that one comes upon them quite suddenly, without any warning of their proximity.

There are but few lakes in Mauritius, although there are many marshes and pools among the lava-beds. The only great sheets of water are the Grand Bassin and the Bassin Blanc, mentioned before, and a few brackish ponds near the coast, in which many fossil bones have been discovered, principally those of the imported deer and of extinct tortoises; but some dodo-bones also were dug up, and there are many bone-beds which would repay a careful search.

The Grand Bassin occupies a double crater, the ridge between the two rising as an island; it is about 650 yards long and 300 wide. The Bassin Blanc is a circular lake in a crater, about 300 yards across. Both are very picturesque, especially the last, which is surrounded by forest-covered cliffs several hundred feet high. There is no visible outflow from either, but the surplus waters find their way through the porous lavas of the sides, and issue on the outer slopes as springs. The Grand Bassin, however, during a hurricane receives so much water (all the rain which falls in the Bassin Sec runs into it) that it rises some 10 or 12 feet, and overflows down a water-channel, which usually is choked with grass and weeds. The principal marsh is the Mare aux Vacoas, which covers nearly a square mile of area. It is situated in a hollow between the Trou Kanaka, Montagnes Cateau, Peruche, and the unnamed crater, christened by the author Ravenala Crater, from the number of those trees which grow in it. The surface of the marsh is covered with reeds and 'vacoa' or screw-pine trees (*Pandanus palustris*); the seeds of this screw-pine float on the water and send down roots many feet long to the soil below, and on these roots, as upon stilts, the trunk stands. There are other marshes, all very much smaller than formerly: the Mares de Pétrin and Longue near the Brise de Fer mountains, d'Houil in Grand Port, and Lubin in Flacq are the principal. Except during the rainy season, all of them can be crossed on foot.

The principal surface-tracts of lava-beds are situated in the gaps in the mountains mentioned before. There is also a large area of them at Ripailles, and another at Vacoas, the former being the outpourings of the Grand Trou North and the Caves Crater, and the latter coming probably from the Trou aux Cerfs. In these tracts lava-flows can be traced sometimes for many miles, as thin rounded masses winding about in snaky courses, with occasional hummocks of broken boulders or cindery scoriæ. These districts are all honeycombed with

caves, and here and there one meets with strange phenomena. At Vacoas there are a number of caves of no great extent, but many of them contain water, often affording the only supply of that necessary of life to the inhabitants of the surrounding district. Not far away is one of the most striking examples of a river flowing some distance underground, at a spot called l'Eau Coulée. It is about 2 miles from Curepipe, on the Port Louis road. Within a stone's-throw of the highway on the right, runs a main tributary of the Grand river N.W., at this point the size of a fair trout-stream, in a shallow wooded gully. It enters a cavern through the centre of a lava-flow, high enough to walk into. The roof is broken through in four more places lower down, at one of which another stream comes in from another cave; and, finally, a hundred yards or so away there is a deep pool in which the water can be seen welling up, carrying sticks and leaves with it, and thence it flows off over a rocky course into a ravine. It appears strange that another stream should rise close to the mouth of the cavern, run within 10 feet of the river in the cavern, and then diverge and disappear amongst the rocks, probably feeding the tributary stream in the cavern. It is a fact worth noting that one of the openings in the roof of the cavern was 'burst up' by the water, during the hurricane in February 1876, and this probably furnishes a clue for the explanation of the fact that so many of the caves amongst the lava-flows are broken through.

Between the Corps de Garde mountain and Montagne Ory, at a place called Petite Rivière, there is a beautifully perfect cave, like a railway-tunnel, in solid lava, with ledges of the same a few feet above the ground, running along the sides. The cave is about 30 feet high and the same wide, with an arched roof. The writer followed this cavern for $1\frac{1}{2}$ mile, until he found it nearly filled up by detritus brought in by a stream, whose bed was well-marked. A current of air passed through downwards, and, as on the coast 3 miles away there are lava-cliffs full of caves, it seems probable that this cavern communicates with some of them.

It is difficult to account for the origin of caves of this description; probably they are formed somewhat in this manner:—A slowly flowing lava-stream descends a gentle slope; it reaches a steeper descent and its flow is accelerated; the centre, the most liquid part, is drawn out, leaving the cooled and hardened roof and sides, its place being taken by steam and other gases given off by molten lava. The bubbly lava-drops from the roof and on the walls would thus be explained, and the ledges would represent levels at which the lava stood longer than usual. Or these caves might be caused by the molten centres of lava-streams flowing on after the supply from the craters had ceased, and thus leaving hollows behind them. In the Petite Rivière cavern there are seven ledges distinguishable, all very scoriaceous. The upper one is covered with layers of lava which appear to have trickled down the walls. This theory explains why the roof, sides, and floor are all in one mass of solid rock, which it would be difficult otherwise to account for.

Underground rivers are common wherever there are lava-beds, and some have been met with at great depths; on the Labourdonnais estate one was tapped at a depth of 92 feet, and another was found on sinking a well near Grand Bay, at a depth of 70 feet.

Among the cliffs which form part of the coast are several remarkable natural curiosities. One of the finest of these is a blow-hole called the Souffleur; it is in a high lava peninsula, honeycombed beneath with caverns into which the sea rushes. In the roof of one of these is a hole about 2 feet in diameter, up which the water is forced, when the height of the waves is great enough, generally when the wind is from the south. The water rises in a magnificent jet, 60 or 70 feet high, with a roar like thunder that shakes the cliffs around. The top of the jet curves over, and falls like an enormous drooping ostrich-feather.

Another curiosity is the Pont Naturel, a double-arched bridge with two spans of about 25 feet each, and supported in the middle by a natural pillar 30 feet high. This has been caused by the roofs of two contiguous caverns being broken through, leaving a narrow piece of their roofs standing, supported on part of the original division between them. The sea roars through the bridge and into the cavern beyond, sending up clouds of spray, and slowly but surely eating away the supports.

The next extensive tract of lava-flows is in Flacq and the upper parts of Moka. They all apparently have issued from the craters of Maccabée, Baisse, Grand Trou North, and the Caves. For several miles along the slopes there are no rivers, marshes abound, and caverns—generally containing water—are of frequent occurrence. The lower part of these lava-flows, called the Plaine des Roches, is nearly flat, and here the molten rock has spread out in sheets, which in many places are only a foot or two thick, and cover a stratum of ash. These lava-flows are full of caves and steam-holes; one of the latter, called the 'Puits des Hollandais,' is worthy of notice. The hole is nearly circular, with a bell-mouth, and about 35 feet across. It is filled with water to within 15 feet of the ground-level. The sides are perfectly vertical, and the author found the depth with a sounding-line to be from 82 to 86 feet in different parts. The water is beautifully clear and fresh, and, strange to say, its level has never been appreciably altered, although a steam-pump, now disused, withdrew a 6-inch stream night and day for a year and a half for irrigation purposes. It is a curious fact that there is a pass in the reef just opposite the Puits des Hollandais, although there is no stream on the surface. Unless we adopt the supposition of a large subterranean reservoir being in connexion with this hole, which keeps it at the same level, and also flows to the sea by underground channels, it is difficult to account for the phenomena.

In the Plaine des Roches, near Roche Noire, are two caverns containing running water, which formerly was pumped up for

irrigation. The upper cavern is in a solid mass of rock; its height is about 40 feet, and width 60 or 70; it divides into two smaller ones, which can be followed for some distance. The roof appears to have been broken into by a later lava-flow, which flowed in and partially filled up one side; in its steep, treacly-looking slope are cracks out of which water wells up into the cavern and runs away down the two small ones which it divides into. The other cavern containing a stream of water passes under the road, but cannot be followed far because the fragments broken down from the roof fill up the opening. On the sea-coast close by are a number of inlets, at the end of one of which can be seen the opening of a cave. The water at this end is quite fresh and issues below the surface, from the cave, in a strong stream; the inlet itself appears to have been formed by the roof falling in, for it is deep and narrow, with vertical sides.

In the upper part of Flacq there is a very strange dry ravine which extends for about $1\frac{1}{2}$ mile; it is caused by the roof of a cavern falling in, leaving broken vertical walls, in some places as high as 80 feet. Every 200 or 300 yards are pieces of the roof remaining in their original position, and forming natural bridges across the gully. The roof in most places has sunk bodily, and the bottom of the gully is often paved with broad lava-sheets showing ripple-marks, while in other parts it is filled with luxuriant vegetation. This is really one of the strangest natural curiosities in Mauritius, but on account of its out-of-the-way position it is little visited. In the 'Caves' crater (a cluster of seven), from which many of these lava-flows have come, there are five dome-shaped caves, all in solid rock. From their position and structure there can be little doubt that they have been formed by the columns of molten lava, in the craters, sinking and leaving their cooled crusts as roofs; lava-drops trickled down the sides, and here and there the molten rock remained at the same level long enough to allow of a crust beginning on its fresh surface, which remained as a horizontal ledge running round the cave. In one of the small craters there is a little conical hill, down the centre of which is a funnel-shaped hole, 54 feet deep. Probably this was one of the last cones thrown up by the dying volcano, and has not yet been long enough exposed to the weather to become obliterated.

Off the coast of the Rivière du Rempart district is a low island called Ile d'Ambre; it is composed of lava-beds, and has a number of strange circular holes, some of them over 100 feet across, 20 or 30 feet deep, with rocky, vertical sides, and partly filled with sea-water. They look as if caused by the falling in of roofs of circular caverns, but probably they are only unusually large steam-holes.

II. Geology.

Mauritius does not offer a varied field to the geologist, for the greater part of its surface is composed of a volcanic breccia: that is to say, angular fragments of lava, usually full of bubble-holes

embedded irregularly in a matrix composed of volcanic ash and earth, caused by the decay of the rocks. Here and there stray lava-flows and sheets occur in the sections exposed in the ravines, and sometimes on the surface, to the loss of the sugar-planter. The volcanic ash is sometimes in thick layers without a stone, as at the Tamarin estate; sometimes its colour is exceedingly variable, as at Chamarel, where seventeen different shades have been counted in the space of half an acre. Sometimes the ash is burnt, by contact with lava, into a kind of red brick, and among the older lavas it is so indurated as to resemble stone. It occurs in places as a fine clay, in others as a coarse gravel, and even as a crumbling rock, in which concretionary nodules are frequently seen.

The commonest rock in the island is basalt, of which the variety called dolerite is the most abundant. This is fortunate, for it is a very perishable rock, and the earth derived from its 'weathering' forms a fertile soil. The doleritic lavas appear to have been mostly ejected from the craters along the central ridge, which were thrown up in the second period of volcanic activity. They form nearly horizontal, terraced plains in the centre of the island, rising to 2328 feet above the sea-level. At the period of their ejection the island was covered with some sort of vegetation, for on the edges of some of these lava-flows, in their scoriæ, are found traces of vegetable tissues, charred and blackened of course, but still recognizable as wood.

During the first period of volcanic activity the lavas ejected were, as I believe, principally diorites, of which the greater number of the mountains appear to be composed. These rocks occur most abundantly in the Black River district, where the easily weathered dolerites have nearly all disappeared. The rocks which I call diorites are very dark in colour, owing to their containing a nearly black hornblende, and thus the mud and débris, brought down by this river, are of a sombre hue, and have given it its name. The later lavas abound in a glassy felspar (probably orthoclase), frequently causing the rocks in which it occurs to become porphyritic. They contain more lime than the older lavas, and in their caves stalactites several inches in length are to be found. Sometimes the lime has crystallized in veins as calcite, but more frequently it occurs in the bubble-holes of masses of scoriæ, making them amygdaloids.

The Mauritius basalts contain a large proportion of lodestone or magnetite, which at one time was worked for the iron it contained. This is a great drawback to the surveyor, for the compass becomes perfectly useless anywhere in the neighbourhood of one of the mountain-masses or extinct craters.

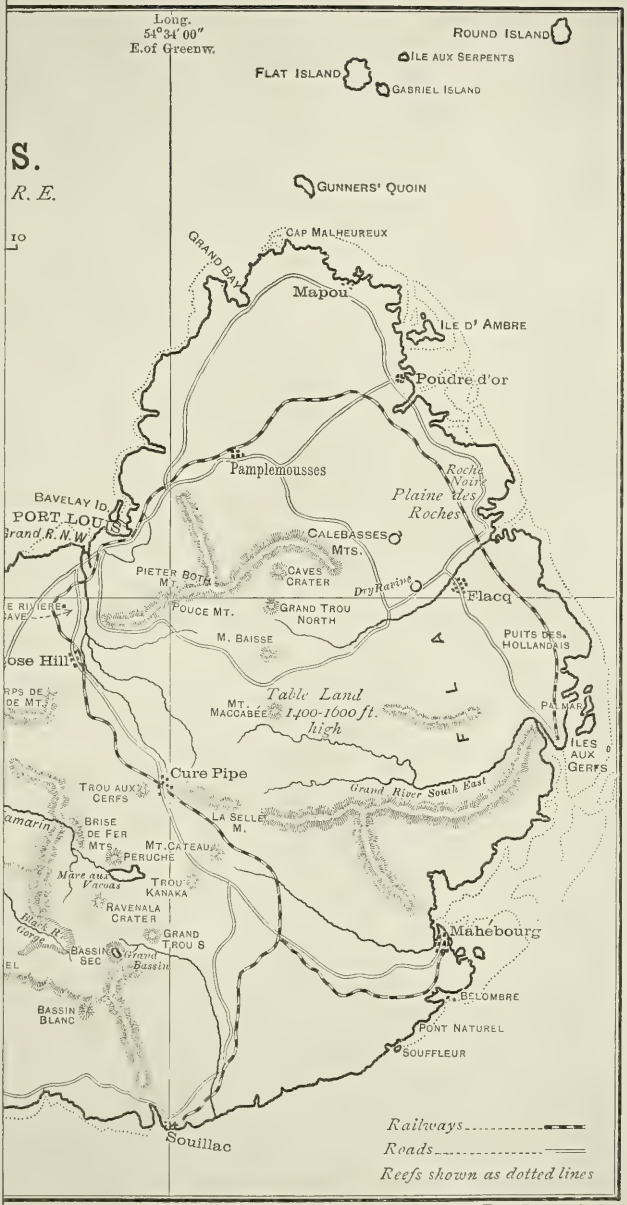
There is evidence of variations of level and of an elevation of the whole island in recent times, for masses of coral-reef and beach-coral rocks are found at elevations varying from about 40 feet in the south to 12 feet in the north, and to 7 feet in the islands on the bank extending to the north-east. A conglomerate, of rolled basalt-blocks and pebbles embedded in a matrix of coral-limestone,

occurs near Arsenal Bay at an elevation of about 13 feet, while close by, some feet lower, is a mass of raised reef-coral. In many parts of the island there are plains of coral-sand and débris, several feet above the sea; the principal are Grand Bay, Pointe aux Sables, Tamarin Bay, Black River Bay, the Morne Brabant, Bel Ombre, near Mahébourg, and at Palmar estate in Flacq. Besides, many of the small islands close around Mauritius consist of nothing but coral-rock, originally forming part of the fringing-reefs before the elevation; such are the Iles Roche, Marianne, Fous, Fouquets, Vaquois, de la Passe, les Bénitiers, while those called Barclay Island and Ile du Morne, etc., are nothing but coral débris. Others again are wholly or partly of volcanic origin, such as Ile Ronde, Ile aux Serpents, Pigeon Rock, Flat Island, Gabriel Island, Gunner's Quoin, Ile d'Ambre, Iles aux Cerfs, aux Egrettes, aux Singes, Fourneau, Souffleur, etc.

The most interesting feature of Mauritian geology is the occurrence, in at least two places, of sedimentary rocks at considerable elevations; one is in the Black River Mountains, near the Chamarel road, at about 1200 feet above the sea, and the other near Midlands, in the Grand Port group of mountains, at an elevation of about 1700 feet. The first is a coarse clay-slate which stands up out of the volcanic rocks in a little hill, covered with vegetation of different species from that clothing the surrounding slopes. The lines of bedding are very indistinct, but appear to be approximatively horizontal. The beds near Midlands consist of crystalline chloritic schist, and form a mountain called La Selle, which stands up bare of trees among the luxuriant tropical forest covering the surrounding hills, and only clothed with grass and a few scattered bushes, principally of heather. The lines of bedding are distinct, especially on weathered surfaces, as are also the imperfect lines of cleavage. The thickness of the strata cannot be less than 300 feet; they are bounded by cliffs on three sides, and, although much contorted, appear to have a general dip to the south or south-east. The talus at the foot of the southern cliff contains coral, serpulæ, and beach-sand, showing that this hill once stood up as an island in the sea, which then probably covered the as yet unformed Mauritius.

These sedimentary rocks could hardly have been formed from the sediment washed down from Mauritius, before it reached its present shape and size, and they point to the existence of a more extensive land at no great distance.

There is a fact which would also lead one to suspect that land, which has since disappeared, once existed in the Indian Ocean, this namely, that the ruling race in Madagascar, the Hovas, are of a Malay type, and speak a language allied to Malay. They have a tradition that they came from over the sea, and the place of their landing is approximately known by the ruins of iron-smelting furnaces, they being the race which introduced that art into the island. One can hardly believe that they came all the way from Malacca, or Sumatra, without touching at any intervening land, and if they did land anywhere they surely would have left some trace. But



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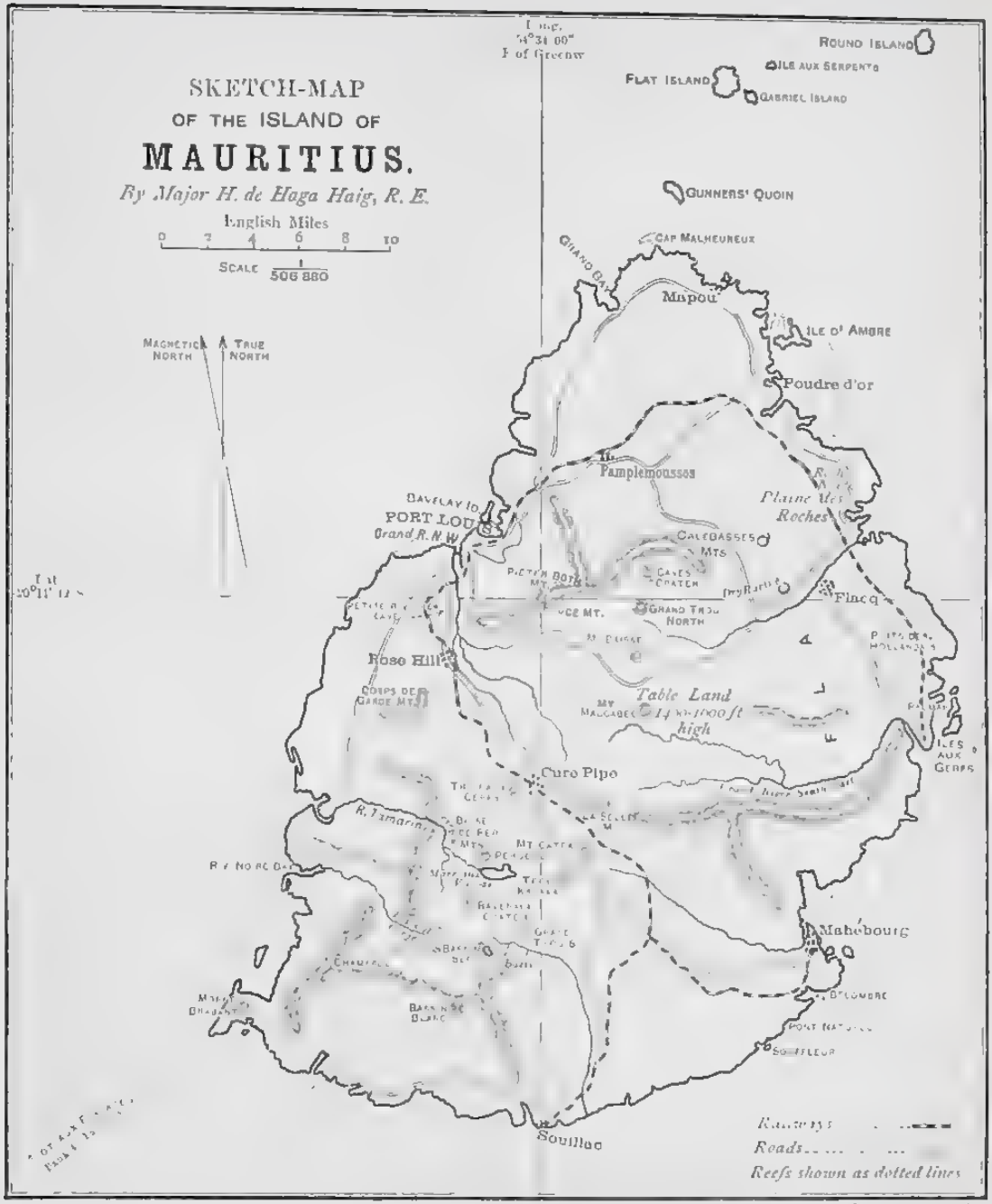

SKETCH-MAP
OF THE ISLAND OF
MAURITIUS.
By Major H. de Haga Haig, R. E.
English Miles
0 2 4 6 8 10
SCALE 1/506 880
Long. 57°31 00" E of Greenw
ROUND ISLAND
ILE AUX SERPENTS
FLAT ISLAND
GABRIEL ISLAND
GUNNERS' QUOIN
CAP MALHEUREUX
Mapou
ILE D' AMBRE
Poudre d'or
Pamplemousses
Plaine des Roches
PORT LOUIS
Grand R. N.W.
CALEBASSES
Mts
Pieter Both Mt.
Signal
Pieter Both
Vacoas
Grand River North
Flacq
Rose Hill
Corps de Garde Mt.
Table Land
Mt. Malcabee 14 hundred ft high
Curepipe
R. Tamarin
Mt. Cater
Mahébourg
Souillac
Magnetic North
True North
Railways
Roads
Reefs shown as dotted lines

where is there any trace existing? The Mascarene Islands contained none, and when discovered were totally uninhabited except by birds and tortoises.

PLATE XV.

Sketch-map of the Island of Mauritius on the scale of $\frac{1}{506,880}$ = 8 miles to the inch.

DISCUSSION.

Prof. T. RUPERT JONES spoke of the paper as having much value in both its description of details and its treatment of subjects of more general interest.

Dr. J. W. GREGORY thought that the record of the schists in the island was of considerable interest; the Seychelles are known to contain schists, but Mauritius is usually described as wholly volcanic. He thought that better support for the view of a former land-area could be obtained from the distribution of the Negrito than from the nautical Malaysian race.

31. *The* Shelly Clays *and* Gravels *of* Aberdeenshire, *considered in* Relation *to the* Question *of* Submergence. By Dugald Bell, Esq., F.G.S. (Read May 8th, 1895.)

The high-level shelly gravels and clays of Aberdeenshire were described in some detail by Mr. T. F. Jamieson, of Ellon, in two valuable papers read to this Society in March 1882.[1] They have also been treated of at some length by the Geological Survey of Scotland, in their published memoir relating to the district.[2] As these deposits have been frequently, and quite recently, referred to as proving a submergence in Scotland during Glacial times, to the extent of 500 feet or upwards,[3] I would ask leave briefly to review the facts, for the purpose of showing that they do not lead to or warrant such a conclusion.

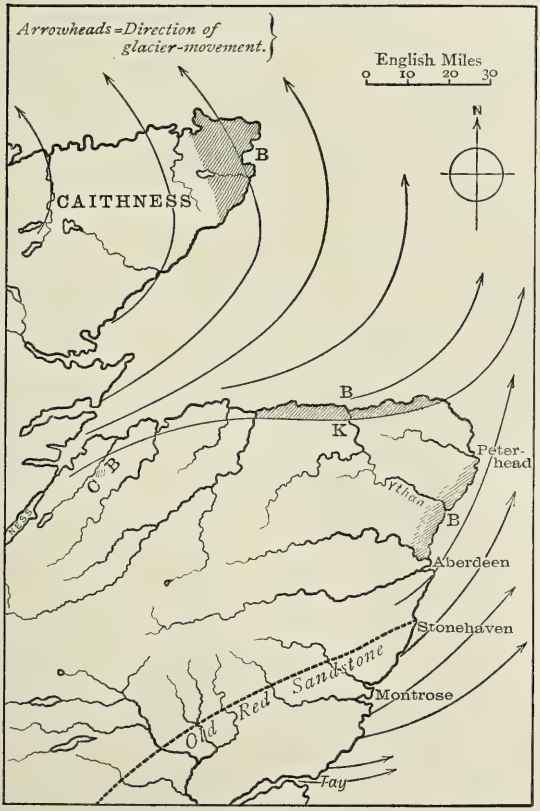
1. There are, first, certain beds or undulating ridges of sand and gravel which, according to Mr. Jamieson, contain fragments of shells of Crag species. These extend along the sea-shore and for some distance inland, a few miles north of the river Ythan, and are found up to a height of 225 feet above the sea, but chiefly between 100 and 200 feet. They rest on the grey Boulder Clay of the district, which is formed of the débris of the gneiss, granite, and mica-schist rocks prevailing there; but they are different from it, containing many pieces of yellow limestone and calcareous shale belonging to some Secondary formation not found *in situ* in Aberdeenshire. 'The shelly material occurs generally in the form of fine pounded débris and small worn crumbs, with here and there a larger bit, generally a hinge.' The evidences, as a whole, indicate transport from the southward, and the inference is that, after the deposition of the grey Boulder Clay, there had been a change in the movement of the ice, bringing it more from the southward, and that some patch of Crag along the coast, or near the estuary of the Ythan, had been scoured out, and the débris carried northward and partly inland by the ice in its progress. In short, Mr. Jamieson considered that 'the gravel represents the scourings of the surface which the ice carried along with it and shed off along its border.'[4] In this view it is a purely glacial deposit, and cannot be cited as evidence in favour of even a moderate submergence.

2. Overlying this shelly gravel is a well-marked bed of red clay which extends over a somewhat wider area, covering much of the low ground between Aberdeen and Peterhead. It ranges from the sea-level up to about 300 feet, 'although there are here and there some indications of it at a higher level.' These indications consist of numerous water-worn pebbles of quartz and flint, similar to

[1] Quart. Journ. Geol. Soc. vol. xxxviii. pp. 145, 160.
[2] Mem. Geol Surv. Scotl. 1886, Expl. Sheet 87.
[3] J. Geikie, 'Great Ice Age,' 3rd ed. pp. 139, 166.
[4] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 152 *et seqq.*

those in the clay, found up to 470, and a scattered few of the same kind up to 560 feet. On the assumption that the clay is a submarine deposit, these pebbles are taken to indicate the limit of the submergence, which is thus currently stated to have been about 560 feet. Nevertheless, we think it clearly appears, from Mr. Jamieson's minute and faithful description of this clay, that it is as truly a glacial deposit as the underlying gravels, to which reference has already been made.

Sketch-map showing the Movement of Ice along the N.E. coast of Scotland.



B=Boulder Clay containing sea-shells.
C=Clava. K=King Edward.

This clay, Mr. Jamieson remarked, 'is not such a deposit as would be derived from the rocks of the district in which it occurs'; it is quite unlike the grey Boulder Clay derived from the gneiss and

granite; but 'looks more like what we should expect to find in a district of Old Red Sandstone, being of a decided brick-red colour, exactly resembling the clay we find in the Red Sandstone district of Kincardine and Forfar.'[1] It also contains large round pebbles of grey quartz with a smooth reddish exterior, such as are met with in the Old Red conglomerate of Kincardineshire. Moreover, it contains many stones of a volcanic nature, unlike the rocks of Aberdeenshire or the North of Scotland, but resembling the masses of trap which occur in the Old Red district of Forfar and Kincardine.

Other evidence exists, in the transport of local rocks, to show that there has been a movement of the ice from the south; and the striæ on some points along the coast, showing first an older set from the W.S.W., or interior of the country, and then a newer set nearly from the S., or parallel to the line of coast, together with the 'hard and tough' appearance of the clay itself in some parts, convinced Mr. Jamieson that the agent was land-ice, which came from the southward 'along the coast, grazing the surface of the rocks at the projecting headlands, and bringing with it the red clay and débris of the Sandstone formation.'[2]

The reason of this northward movement of the ice along the coast was, as Mr. Jamieson also points out, the ice-blocked condition of the North Sea, as demonstrated by Dr. Croll some five-and-twenty years ago,[3] 'so that the Scottish ice would be unable to move out to the eastward, and be compelled to turn along the coast in the direction it seems to have actually taken.'

The conclusions of the Geological Survey on these points agree generally with those of Mr. Jamieson, though in one or two rather important respects they differ. They agree in regard to the general succession being (1) the grey or lower Boulder Clay, (2) the intermediate sands and gravels, and (3) the upper or Red Boulder Clay. They agree also in supposing a first or local glaciation for the grey or lower Boulder Clay, and a later movement of the ice-sheet from the south when the upper Red Clay was deposited. With regard to the latter the Surveyors say that it 'can be traced along the coast as far south as Stonehaven, and there is little doubt that the materials of which it is composed were brought from that quarter.' Again, they refer to 'the ice-sheet that passed to the north and left behind it the upper Boulder Clay.'[4] But they differ in that the Surveyors pronounce the intermediate sands and gravels to be interglacial, and to have been accompanied by a submergence of 360 or probably of 500 feet. The grounds on which this pronouncement rests are not very apparent. We are told that while these sands and gravels 'strongly resemble moraine-stuff,' they have been 'washed and rolled,' and contain 'marine shell-frag-

[1] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) pp. 160, 162.
[2] *Ibid.* pp. 165–66.
[3] Geol. Mag. 1870; also 'Climate and Time,' 1875.
[4] Mem. Geol. Surv. Scotl. 1886, Expl. Sheet 87, pp. 23, 24.

ments mixed through' them.[1] This seems a very insufficient reason for having recourse to the expedient of a submergence. And to adduce the upper limit of these gravels, even where no shells have been found in them, as proving submergence to that extent, is exactly the mode in which a submergence of 2000 feet was at one time thought to be made out by certain high-level unfossiliferous gravels in Wales which are now admitted not to be marine at all. The writer of the Survey memoir says, 'It may be presumed that the interglacial beds here described were accumulated during the same submergence that introduced the shells into the interglacial clays of King Edward and Clava. At the latter place a submergence of 520 feet above present high-water mark is necessary to account for the present position of the shells.'[2] This is surely a somewhat hastily drawn conclusion. Every case must be judged upon its own evidence, and must be clearly proved before it can be made a means of proving others. King Edward and Clava have enough to do to answer for themselves.[3] Considered as evidences of submergence they may both be said to be in a 'parlous state.' To take them as proved and admitted marine deposits in order to strengthen the case for submergence elsewhere is hardly admissible.

Further, the Survey officers differ from Mr. Jamieson in considering the Red Clay simply as an 'upper Boulder Clay' due to the later glaciation. They say nothing about submergence in connexion with it, nor do they take any notice of the marine remains in it, thereby quashing the evidence for submergence on which Mr. Jamieson chiefly relied. The question occurs, why should fragments of shells in the intermediate, 'morainic,' 'false-bedded' sands and gravels be taken as proving submergence, and those in the Red Clay be quietly passed over?

Briefly, Mr. Jamieson took the intermediate sands and gravels as purely glacial, saying nothing about submergence in connexion with them, but thought that the Red Clay did indicate submergence. The Survey officers reverse the finding in these respects; they interpret the sands and gravels as evidences of an interglacial submergence, and consider the Red Clay as purely glacial.

By this diversity of opinion I feel emboldened to state, with all deference, my own view, which is that both the deposits in question are due to the same cause,—the one to an earlier and the other to a later stage of the same glacial conditions, and that submergence is not indicated, far less proved, by either of them.

We have already seen how weak is the case for submergence as inferred from the intermediate sands and gravels. Let us now turn to that which has been made out from the Red Clay.

Having clearly shown, by the facts which we have summarized, the glacial origin of this clay,—that it was due to a great sheet of land-ice moving northward along the coast,—and also stated the

[1] *Op. cit.* p. 22. [2] *Ibid.* p. 23.

[3] The shelly clay at King Edward is only about 150 feet above the sea, and so, in any case, cannot help us much in a question of 520 feet.

reason why the ice moved in that direction, Mr. Jamieson unexpectedly proceeds to consider the 'progress of the submergence.'[1] What submergence? The facts which have just been mentioned—the ice-blocked condition of the North Sea, and a great glacier from the mountainous region to the south creeping up along the coast—seem far from justifying any such hypothesis.

I am rather inclined to think that a submergence of 500 feet or more being at the time he wrote generally accepted, Mr. Jamieson —to whom I would invariably refer with the greatest respect—simply admitted it among his facts, not deducing it from them. Having observed that 'the fine red mud implies deep, or at least quiet water,' he adopted the submergence as furnishing what was required. The first fact, however, which he mentions in connexion with it presents a difficulty. 'There is no evidence at the bottom of the clay of littoral mollusca, such as would indicate shore-conditions at the commencement of the submergence. .... As a rule, it [the fine red mud] lies immediately on the top of the grey Boulder Clay without the intervention of any beach-gravel or sand between them, as if still water of some depth had at once taken the place of the glacier.' To explain this, Mr. Jamieson supposes that the glacier did not break up till a considerable amount of submergence had occurred. 'In this way deep water would take the place of the ice as soon as it floated off the bottom, and the red mud would then settle down on the exposed surface of the grey Boulder Clay.' Then, as the submergence proceeded, the glacier gradually retired, sending out red mud all along its margin. And this process, Mr. Jamieson conceives, would begin at the N.E. corner of the country, where the ice was 'less heavily developed' than elsewhere; the thinnest ice would yield soonest, and the sea-water would thus first establish itself, say, 'in the neighbourhood of Peterhead and Fraserburgh, and thence creep south and west along the coast as the ice gradually broke up.'[2]

Now, there seem to be several difficulties in the way of Mr. Jamieson's theory. The chief and most obvious is this:—It was the ice-blocked condition of the North Sea which compelled the land-ice from Kincardine and Forfar to turn northward along the coast, as it clearly appears to have done. As soon as that condition began to give way, and in proportion as it approached an end, the ice would undoubtedly cease to take that direction and would proceed out eastward to the more or less open sea. The compelling cause of its turning northward being removed, and a more direct exit at the same time set before it, of course it would turn northward no longer. The ice in the North Sea being thus the dominating factor in the case, the question arises, where would it most likely give way first? Be it remembered that it was land-ice, chiefly from Scandinavia, occupying as a solid mass the bed of the North Sea. Can we imagine that in the north, at Peterhead and beyond, that ice had melted away, while in the south, at Stone-

[1] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 168.
[2] *Ibid.* p. 168.

haven, it still invested the sea-bed and blocked the passage? Would it not be thinnest and 'less heavily developed' to the south, and therefore first give way there? Thus it would keep receding gradually northward, the sea becoming more and more open to the south as it withdrew. Accordingly, before—probably long before—it was deep open sea at Peterhead and Fraserburgh, it would be deep open sea in the neighbourhood of Stonehaven, and the ice ceasing, as we have said, to go north, there would be no fine red mud carried thither for deposition in the deep still water when that came. The two conditions thus seem incompatible—the northward-moving ice-sheet excludes the deep water, and the deep water excludes, or precludes, the northward-moving ice-sheet.

Besides, could sea-water afford the tranquillity which seems to have been required for the deposition of this fine mud? Would not waves, and tides, and currents play their part, especially so near the coast, and prevent anything like so fine and, in parts, so 'delicately laminated' a deposit?

Again, why is this deposit, if marine, so 'remarkably devoid of remains of animal and vegetable life?' It is rare to find shells in it, and when they do occur they are very scanty and usually in broken fragments. 'For a marine deposit,' Mr. Jamieson continues, 'the scantiness of fossils is surprising; for the greater part of it seems absolutely barren.' The only explanation he can give is that this extreme sparseness of organic remains 'seems to point to a sea in which marine life was far from abundant.'

Sir Charles Lyell has stated that he once thought 'the absence of signs of organic life in the Scotch drift might be connected with the severity of the cold, and also in some places with the depth of the sea during the period of extreme submergence; but,' he adds, 'my faith in such an hypothesis has been shaken by modern investigations, an exuberance of life having been observed both in Arctic and Antarctic seas of great depth, and where floating ice abounds.'[1] So that the supposition of a sea in which marine life only sparingly existed does not seem very satisfactory.

These being some of the difficulties, one is disposed to ask whether it is necessary to assume that this Red Clay was laid down in the sea at all. It contains marine remains, truly, 'very scantily and in fragments';—is there not every reason to believe that these have been brought along with the Red Clay and the fragments of rocks from a distance, by the ice which moved northward along the coast? And if 'still water' were required for the deposition of the clay (which, by the way, occurs most abundantly, as might be expected, in the hollows and depressions and little valleys of the district), would not that condition most likely be furnished by the ice which passed northward along the coast, blocking the drainage of the adjacent country, and causing 'extra-glacial lakes' here and there along its margin? It seems inevitable that such effects would

[1] 'Student's Elements of Geology,' 1871, p. 154.

be produced at many points where the inland ice did not meet and coalesce with the northward-moving sheet along the coast. Into these bodies of still, tideless water, the fine red mud, fragments of shells, stones from a distance, etc., with which the ice was charged, would be shed and gradually accumulate.

Similar effects were produced elsewhere. Mr. Lamplugh has shown that as far south as Flamborough Head the ice had a thickness of at least 500 feet, overriding the cliffs in many parts and extending to some distance inland, across the mouths of the eastern valleys. 'The drainage-channels of the streams flowing eastward,' he says, 'were dammed by the ice, and lakes were formed wherein deposits of gravel and other material rapidly accumulated.'[1] And the observations of the present writer have led him to believe that similar conditions existed also at Clava.

It seems almost like an anticipation and confirmation of this suggestion that the late Dr. John Fleming, of Edinburgh,—a shrewd and sagacious naturalist, whom Mr. Jamieson quotes as having known the Red Clay well,—'thought it must have been accumulated in the water of some immense lake into which the sea had made only a temporary irruption.' This strikes us as being a remarkable surmise of fifty years ago, when the distinguished author had no idea, apparently, of how such a lake could be formed.

The writer is pleased to add that Mr. Jamieson has courteously acknowledged the probability of the conditions herein suggested.

Discussion.

Mr. Clement Reid said that, although unacquainted with the particular district dealt with by the Author, he was inclined to agree with his explanation of the origin of the shelly deposits. The tumultuous character and the mixed fauna of the Clava sands and Boulder Clay agreed closely with what he had observed in other glaciated districts at heights of over 150 feet.

Prof. G. A. J. Cole remarked that the publication of the paper would be looked forward to with great interest in Ireland, where the extent of shell-bearing gravels and clays made the question of recent submergence of especial importance. The shells were now generally admitted by field-observers, including Mr. Maxwell Close himself, to have been removed from their original habitat. The speaker claimed that the submergence occurred in late Pliocene times, and may have been merely the continuation of that which deposited the Lenham Beds in England. Thus many of the so-called 'recent' species in Glacial beds might easily be derived from Astian or even earlier strata, on which the great mixing influences of the Glacial Period had been exerted.

Dr. Hicks mentioned the deposits containing shells at heights of from 400 to 600 feet in the Vale of Clwyd, North Wales, which are covered by a Boulder Clay with northern erratics.

[1] Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 428.

Mr. G. H. Morton referred to the Glacial drift-deposits of the country bordering the Mersey and Dee, and he considered that they were deposited in the sea between the coast of Wales and the North of Lancashire where glacial conditions prevailed. Beds of inter-stratified sand, often ripple-marked, and sometimes containing rolled balls of clay, divided the Boulder Clay into beds, and frequently gave it a stratified appearance. The shells found in the Boulder Clay had been described as very fragmentary, but the numerous species in his own collection were remarkably perfect. They were all species now living in the Irish Sea, the most abundant being those common on the sea-shore at the present time. All the observations that he had made tended to show that the Boulder Clay and associated sands were deposited in a sea with floating ice, and were not the result of glacier-ice moving over that part of the country.

Mr. Marr also spoke.

32. *The* Stirling Dolerite. By Horace W. Monckton, Esq., F.L.S., F.G.S. (Read May 8th, 1895.)

A glance at the Geological Map of Scotland will show that Stirling Castle stands on one end of a very large mass of intrusive igneous rock. Its continuity has been broken by a long east-and-west fault a little south of St. Ninian's, but if we ignore this break the mass of igneous rock has a length of about 8 miles and a width varying from about $\frac{1}{4}$ to nearly 2 miles.

The rock has been intruded into strata of the lower part of the Carboniferous Limestone Series, and it forms not one, but a number of irregularly-shaped intrusive masses or group of sills, all more or less connected with one another. The hardness of the igneous rock has in many places been sufficient to arrest denudation, and the result is a number of crags, which often resemble Salisbury Craigs, near Edinburgh. Sometimes these crags face the north or north-west, as in the case of Stirling Castle and King's Park, but in other cases they face in a different direction, at Sauchieburn, for instance, the north-east.

As I shall show from the character of the rock, we can have little doubt that the mass of the Abbey Craig north of the river Forth is connected underground with the Stirling Castle rock, from which it is only divided by alluvium, and there is reason to think that the igneous rocks of Cowden Hill and of the hills around Kilsyth are also outlying portions of the Stirling rock. It is not meant that they are outliers, in the strict sense of that term, but that there is an underground connexion between them.

All these patches, as well as the main mass, are for the most part composed of a more or less coarse-grained dolerite, the marginal part always becoming finer grained and more basaltic in character, and the actual edge has apparently been a tachylyte now devitrified.

Extensive quarries for road-metal, in the rock of the Abbey Craig in the north and around Kilsyth in the south, enable one to obtain specimens from the heart of the igneous rock, and I will take as a first example a microscope-section from the rock at the bottom of Wilson's quarry, Barrwood, Kilsyth. It is an ophitic dolerite composed mainly of a plagioclase-felspar—probably labradorite, and of augite, both in a fair state of preservation. The plagioclase-crystals are long and narrow. There is a flecky green mineral, probably a hydrous iron silicate, which is no doubt an alteration-product after pyroxene, though in certain instances it has by some process of infiltration succeeded in invading the felspar. There is a good deal of iron oxide in irregular patches, and numbers of clear colourless needles, sometimes $\frac{1}{10}$ inch long, pierce the other constituents of the rock. They are, I think, usually identified with apatite. Small quartz-granules are scattered here and there, but whether they are a normal product or foreign grains introduced

into the rock I should hesitate to say. In the Geological Survey explanation of Sheet 31 it is suggested that they may be derived from arenaceous strata involved in the molten lava as it rose upwards.[1] A little biotite occurs, often associated with the green alteration-product.

In a microscope-section from the uppermost rock in the same quarry the felspar is still well preserved, but the crystals are of smaller size. The pyroxene is replaced to a greater extent by green mineral.

In another microscope-section, from the quarry close to the railway at Kilsyth, I noticed a crystal of hypersthene, and Mr. Teall showed me one of his sections from near that town in which the same mineral occurred. These are the only sections from the Stirling dolerite in which I have seen it, though I have observed altered crystals which look somewhat as though they had once been hypersthene.

Mr. Allport has figured a section of a rock from Gernal Brae, near Kilsyth, which seems to be a rather fine-grained variety of the rock that I am describing.[2] I call it 'fine-grained,' because the largest plagioclase-crystal shown is only about the size of a medium-sized plagioclase-crystal from the inner part of the rock at Abbey Craig, or Kilsyth. A medium-sized crystal from the former place measures $0{\cdot}039 \times 0{\cdot}012$ inch, and from the latter $0{\cdot}055 \times 0{\cdot}012$ inch.

The igneous rock of Cowden Hill is of much the same character as that of Kilsyth, but in such microscope-sections from that place as I have examined the felspar is not well preserved.

Passing now to the north of Stirling, the rock of the Abbey Craig is very much like that already described. The iron oxide occurs in rather large patches, and frequently in the form of skeleton-crystals or masses broken up into globulites. In one case it seems to have got into cracks in the felspar, and looks almost as if it had formed after the felspar.

Coming now to the main mass of the Stirling dolerite, I would draw attention to some sections from Sir James Maitland's quarry at Milnholm,[3] Sauchie. The rock is much the same as that of Kilsyth and the Abbey Craig. The plagioclase-crystals are large, sometimes 0·35 inch long, and very much altered into a flecky white mineral; the augite is well preserved. The iron oxide, biotite, etc., occur as at Kilsyth, and there is a little hornblende intimately associated with the augite.

At several of the localities mentioned there are in the dolerite pink or white patches and veins, and at the bottom of the Milnholm Quarry the rock has a large amount of pink intermingled with the dark greenish colour. A section from this part of the quarry shows

[1] Mem. Geol. Surv. Scotl. (1879) Expl. Sheet 31, p. 44.

[2] Quart. Journ. Geol. Soc. vol. xxx. (1874) pl. xxxiii. fig. 1.

[3] This quarry is about half-way between Craigend and Craigquarter—the name is sometimes spelt 'Millholm.'

the pink part to be a micropegmatite composed of a felspar and possibly quartz, the former predominating. This micropegmatite acts as a groundmass to the large crystals. These are plagioclase usually much altered, augite well preserved, and a green mineral in long crystals which may possibly be an alteration-product after hypersthene. The iron oxide occurs both in small patches and in long rods which in several cases attain a length of 0·1 inch. These long rods do not occur in my other microscope-sections from the Stirling dolerite.

Mr. T. H. Waller[1] has described red and grey veins in the Rowley Rag, but they do not appear to be of the character of the red rock above noticed, for the felspar in the Rowley Rag vein is described as of larger size than in the rock in the neighbourhood of the vein, whereas in the Stirling rock the felspars of the veins and pink patches are very minute as compared with those of the surrounding rock.

At one spot, a short distance south-west of the house at Sauchieburn, the dolerite is strongly magnetic, so much so as to give trouble to an engineer who was laying out a pipe-track, and who was at first unable to account for the erratic behaviour of the compass attached to his level. Even small specimens of this rock exhibit a distinct polarity, one side showing a tendency to attract the north and the opposite side the south point of the magnetic needle. A microscope-section shows that, excepting for its magnetic properties, the rock is of the ordinary character. The felspar is well preserved, and there is a little brown hornblende associated with the augite.

The more coarsely crystalline part of the Stirling rock has been now sufficiently described, and I pass on to consider the finer-grained, often almost glassy, margin of the intrusive sheets or sills.

This change of character as one approaches the margin has been very fully and accurately described by Sir Archibald Geikie,[2] and I have little that is new to add to his account. The following notes, however, may be of interest.

On the western side of the Sauchie mass of igneous rock there is a magnificent natural section along the valley of the Bannockburn.[3]

Section of Sauchie Craig.

1. Intrusive dolerite forming the top of the Craig; maximum thickness about 100 feet.
2. Carboniferous Limestone Series, consisting of shales and sandstones with one or two thin limestones, known as the Hurlet Limestone. About 130 feet.
3. Calciferous Sandstone Series, not well shown. About 50 feet.
4. Porphyrite. Interbedded with the Calciferous Sandstone Series, shown in numerous sections along the Bannockburn.

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[1] 'Midland Naturalist,' vol. viii. (1885) p. 261.

[2] 'Carboniferous Volcanic Rocks of the Firth of Forth Basin,' Trans. Roy. Soc. Edinb. vol. xxix. (1879) p. 496.

[3] See the diagrammatic section through Sauchie Craig, Proc. Geol. Assoc. vol. xii. (1892) p. 251.

At the northern end of the Craig are some disused limekilns, and above them the junction of the igneous rock and the underlying strata is very well shown.

The strata are inclined at a low angle, and the bottom of the igneous rock, which is nearly horizontal, cuts across the bedding. At the kilns the level of the bottom of the igneous rock is about 400 feet O.D., and 60 or 70 feet above the Bannockburn.

The Hurlet Limestone has in former times been worked under the igneous rock, and close to the mouth of an old level (part of the old workings) the bottom of the igneous rock descends abruptly through the strata. It soon rises again, however, and at a place locally named the Goat's Mouth[1] it has risen to a level of 600 feet O.D.: that is, some 200 feet higher than at the limekilns.

The jointing of the igneous rock is almost vertical or slightly inclined to the south. In one place a prominent vertical vein of calcite runs through it, and just south of the vein the igneous rock again rises up through the strata, giving good evidence of its intrusive character.

For a long distance southward excellent sections showing the junction of the igneous rock with the underlying strata are to be seen, but it is unnecessary to describe them in detail. At one place a mass of strata about 12 feet thick is partially enclosed in the igneous rock. That is to say, it has about 8 feet of igneous rock below and about 30 feet of the same rock above it. It consists of the very much altered whitish shale locally known as 'calm.'

The greater part of the igneous rock is the more or less coarse-grained dolerite, which we have been describing from other parts of the mass, but as we approach the edge a change takes place, and the grain becomes gradually finer. A microscope-section taken 5 inches from the bottom shows:

(*a*) That the rock is beginning to assume a porphyritic character, some of the crystals of plagioclase being of larger size than the others.

(*b*) There is no augite to be seen, though there is a little green mineral which is perhaps an alteration-product after augite: probably the rock solidified just as the augite was beginning to come out of the groundmass.

(*c*) There seems to have been once a certain amount of partially individualized groundmass, perhaps even a glassy base in the rock.

(*d*) There are collections of straight hair-like iron oxide which sometimes form a network, and small hairs and rods of iron oxide are scattered through the slide, in the manner shown by Sir Archibald Geikie in one of his sections.

(*e*) The rock effervesces freely with cold hydrochloric acid.

This rock becomes slightly more porphyritic as it gets nearer the bottom, and a section cut perpendicularly through the bottom

[1] Name not on the maps.

shows porphyritic felspars (which are much decayed) in a dark grey groundmass, consisting in the upper part of the slide of minute felspar-crystals, but lower down being almost wholly composed of iron oxide. There is no augite, nor do the iron-oxide rods or hairs of the last microscope-section appear. A band about 0·08 inch thick at the bottom of the igneous rock is marked by what may perhaps be an approach to a spherulitic structure; that is to say, there is a tendency on the part of the granules of iron oxide to form small globular aggregates.

So far as I can judge from an inspection with a lens, the same class of change takes place all along the margin of the igneous rock in Sauchie Craig, and I have some microscope-sections from Cowden Hill which show similar characteristics.

An outlying patch[1] of igneous rock at Touchadam Quarry, 150 yards west of the Sauchie Craig mass, and on the opposite side of the Bannockburn, furnished me with another specimen showing the junction of the igneous rock and underlying white altered shale. A microscope-section cut through the junction shows in the upper part of the slide a grey groundmass with porphyritic plagioclase-crystals which are much changed. Here and there are granules of quartz, associated sometimes with iron oxide. The quartz is probably secondary, filling up minute vesicles, on the edge of which it is possible that the iron oxide formed in cooling. An examination of the rock shows that this porphyritic portion is several inches thick. At the bottom of the igneous rock there is a zone, about 0·11 inch thick, of very hard black rock, with an indistinct spherulitic structure. The groundmass is in places formed into irregular lines showing a flow-structure along the bottom of the rock. Sometimes the porphyritic felspars are more or less parallel to the bottom, but they are often set at various angles and the lines of flow curve in and out amongst them. These felspars frequently contain enclosures of iron oxide. The line of junction is irregular, but well defined. At one point a portion of the underlying rock is partially enclosed in the basalt. The underlying rock is a white indurated shale ('calm'). Granules of quartz are scattered through it, and along the junction are collected together in places.

I now cross over to the eastern side of the Stirling mass of igneous rock, in order to describe its contact with the overlying strata, and I have, with the assistance of the 6-inch map, prepared a sketch-map of the locality (fig. 2, p. 486), to which I more especially wish to draw attention.

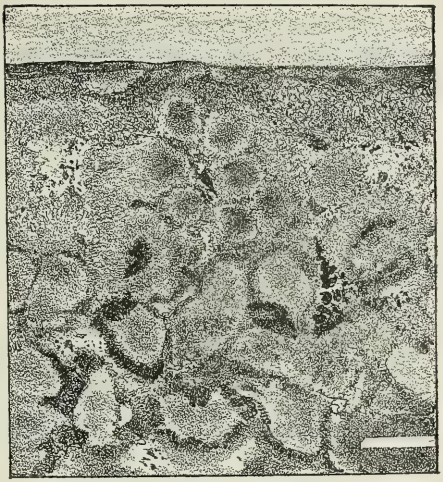
Between the points marked 1 and 2 on the sketch-map there are some exposures showing the igneous rock and its contact with overlying shale. Some specimens from locality 2 were described by Mr. J. G. Goodchild in an appendix to my former paper, and I am much indebted to him for assistance in working out the geology of this district.[2]

[1] This patch is shown on the 6-inch, but not on the 1-inch Geological Survey map.

[2] Proc. Geol. Assoc. vol. xii. (1892) p. 252.

This junction at the top of the igneous rock resembles generally the bottom-junction at Sauchie Craig and at Touchadam above described. The top is marked by a well-defined, though irregular line, and at one spot a projecting point of shale is partially surrounded by the igneous rock. A portion of a micro-section cut through the top of the rock is shown in fig. 1. There is not the flow-structure of the Touchadam specimen, and the porphyritic felspars are lying at all angles. The groundmass is, however, very dense, and I think that if it were slightly transparent the lines of flow might probably be seen twisting in and out amongst the felspars, as at Touchadam. Indeed, in the portion figured there are indistinct signs of flow-structure in the lower part of the figure.

Fig. 1.—*Junction of basalt and shale.*



× 70.

The felspar is very well preserved, and in this the rock differs from the bottom rock of Sauchie Craig and Touchadam. There is here a more or less distinct spherulitic structure in the uppermost zone, which is some 0·18 inch wide.

The groundmass is mainly composed of oxide of iron for a distance of about 1 inch from the top, and then minute crystals of plagioclase appear in it, the larger porphyritic plagioclase-crystals continuing throughout. This rock effervesces with acid, but less so at the top than 2 inches down. For other features of this locality I would refer to Mr. Goodchild's account.[1]

Near Sauchieburn there is a good deal of the white altered shale locally known as 'calm,' and it has been worked in a small pit at the point marked 3 on the accompanying sketch-map.

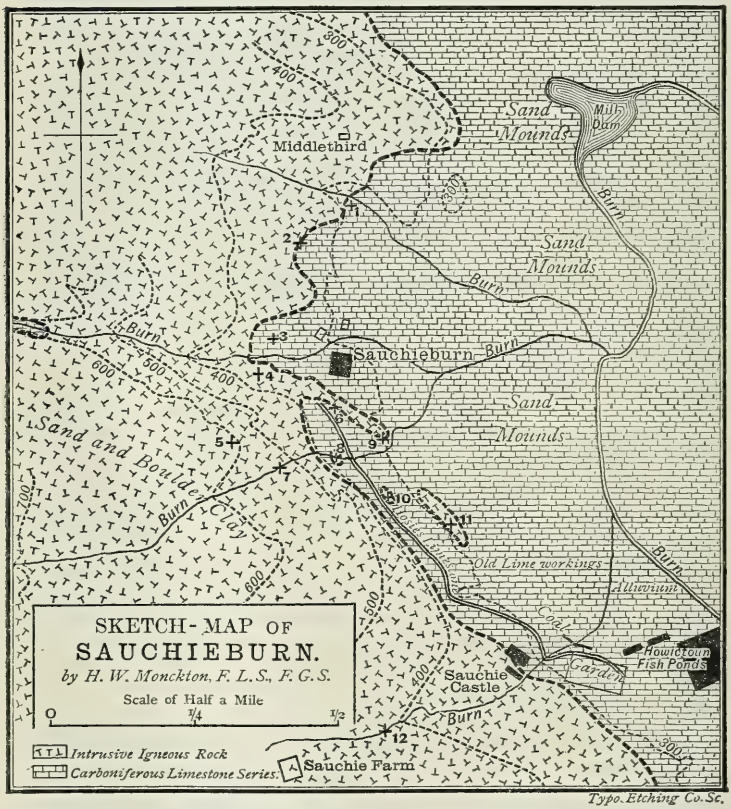
South-west of the house at Sauchieburn (see sketch-map, fig. 2, p. 486) the igneous rock rises in a picturesque cliff nearly 300 feet high. If one climbs up it in a south-westerly direction one finds a series of four ridges rising one above the other, composed of igneous rock. In several places on the two lower ridges one may find ice-marked surfaces of rock, and if these are carefully examined it will be found that the scratched rock is the indurated shale,

[1] *Op. supra cit.*

which comes in contact with the igneous rock, or in some cases the hard margin of the igneous rock itself. The unusual hardness of the marginal part of the igneous rock and the shale in contact with it has been sufficient to arrest the denuding agents which have removed the overlying strata.

As one ascends, however, the igneous rock at the surface becomes a dolerite, and in the upper ridges its coarse grain shows that the marginal parts of the igneous rock have been wholly removed.

Fig. 2.



Typo. Etching Co. Sc.

If one follows these ridges of igneous rock to the south-east, one finds that the lowest runs out in a long tongue, as shown in the sketch-map; that the second ridge soon ends off against sandstone, while the upper ridges continue as a high crag underlain by stratified rocks, and facing the north-east. The high ground above this crag and away to Sauchie Craig is covered with Boulder Clay and Glacial Sands and Gravels, which are no doubt more or less underlain by igneous rock.

There are some interesting sections in the burns which rise in the Glacial deposits and flow in an easterly direction. I will take first the burn south of the house at Sauchieburn (see sketch-map facing this page). It rises above the 700-feet contour, but there are no exposures of rock above a level of about 570 feet. A short distance north of the burn, at the point 5 on the sketch-map, there is the rock with the peculiar magnetic characteristics which has been already described.

At the point 7 there is fairly coarse dolerite, and close to it the burn falls over the cliff. At the bottom of the waterfall the rock is fine-grained, and is underlain by an indurated altered sandstone of a light colour which might perhaps be called a quartzite.

At the point 8 on the sketch-map there is more igneous rock in the burn. It rests against the stratified beds, and is no doubt a small offshoot from the main mass of intrusive igneous rock. It is of the fine-grained type, almost porphyritic, with minute rods and hairs of iron oxide in bundles here and there. The porphyritic felspars, which sometimes attain a length of 0·02 inch, are almost wholly replaced by alteration-products. The rock is full of carbonates in minute specks, and effervesces freely with acid. No doubt these are marginal characters, and the rock, if worked into, would probably turn out to be a dolerite.

Resting against this igneous rock is a brown shale, and below the shale a bed of limestone, probably one of Hosie's seams, as indicated on the sketch-map.

The limestone has undergone alteration and is dolomitic in places, and does not always effervesce with cold hydrochloric acid. It is extremely hard and contains a great deal of pyrite.

Under the microscope, using a fairly low power, it is seen to be crowded with small specks of hexagonal or roundish shape, and about 0·02 inch in diameter. They are white by reflected light, and seem to be isotropic. Under an $\frac{1}{8}$-inch objective some of them are seen to have a distinct radiating structure around a central nucleus. This is shown in fig. 3, p. 488.

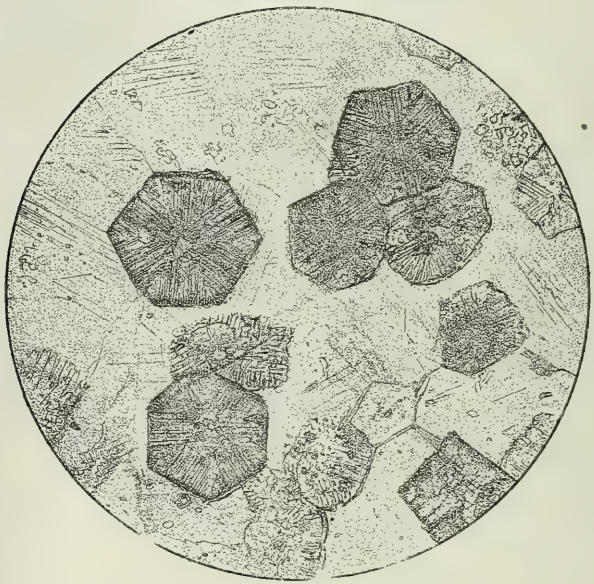
Patches of iron oxide occur in this limestone and partake to a certain extent of the form of some of the patches of iron oxide in the marginal part of the igneous rock, with similar hair-like projections and minute rods.

At the point marked 9 on the sketch-map, a few yards north of the burn, we find a third occurrence of igneous rock just above the 300-feet contour. It is the projecting part of the lowest ridge described above.

At the point marked 6 in this ridge I saw, in 1893, a section showing the top of this igneous rock and its junction with the overlying shale. The shale is white and much altered. The upper part of the igneous rock is of a dark blue colour, with a yellowish band near the top. The top does not effervesce on treatment with acid, but effervescence begins 0·40 inch down, and still lower there

are numerous small vesicles filled with calcite. I have two microscope-sections from this rock, one cut through and at right angles

Fig. 3.—*Dolomitic limestone.*



× 450.

to the top, the other cut nearly parallel to the top 3·70 inches below it. Under the microscope the following characteristics appear :—

(i) The top zone, 0·02 inch broad, is yellowish-green and grey in colour. There is not the spherulitic structure of the specimen from locality 2 (p. 485), though there seems to be an approach to it in the aggregates of iron oxide which give a speckled appearance to the groundmass. The felspars are porphyritic, but small and greatly altered.

(ii) A zone 0·10 inch thick, in which the groundmass is grey in colour and very fine-grained. The porphyritic felspars are long and thin ; a large one measures 0·02 × 0·003 inch ; many of them are fairly parallel to the top of the igneous rock.

(iii) A greenish-yellow band 0·15 inch thick, with brown blotches and well-preserved felspars which are white, though yellow colouring has occasionally invaded small cracks in them. This yellow colour is, I should think, probably due to the nearness of the specimen to the surface of the ground.

(iv) A zone 0·22 inch thick, with a grey groundmass more clouded than zone ii. iron oxide in minute specks, and porphyritic felspars.

(v) At the bottom of the microscope-section—that is, 0·7 inch from the top of the igneous rock—minute laths of felspar are beginning to appear in the groundmass in great numbers. The porphyritic felspars as before.

The whole structure of the uppermost part of this rock is suggestive of rapid cooling, and the microscope-section 3·7 inches from the top shows the porphyritic rock which we seem always to find between the basaltic edge and the dolerite-centre of the intrusive sheet.[1]

In the other microscope-section, 3·70 inches below the top, the groundmass is composed of lath-shaped felspars, and there may be a little minute granular augite; but if so, it is in very small quantity. The porphyritic mineral is plagioclase as before. The iron oxide is in the form of small globules and minute rods, which latter are collected in groups and cross one another usually at right angles, forming a sort of trellis-work.[2]

A short distance north-west of this locality, at the point marked 4 on the sketch-map, there is a small quarry in which the igneous rock is of an amygdaloidal character.

At the surface of the ground there is a little shale, and the top edge of the igneous rock is very well shown. I have a microscope-section taken $5\frac{1}{2}$ feet below the junction. The rock is not porphyritic, though the plagioclase-crystals are of variable size (0·015 × 0·004 is an average measurement). There is a certain amount of augite which has been much altered, and some dark-coloured mica. A good cross of felspar is seen close to one edge of the slide. There is a tendency on the part of the felspars to arrange themselves in star-shaped groups. The iron oxide occurs in patches and globules and in minute rods, which are frequently long and hair-like. These rods and hairs are often arranged in patches, one of which measures 0·09 × 0·05 inch; the hairs very often have a small knob at one end. The amygdules, which are numerous, consist of a green mineral, which is probably serpentinous, and iron oxide.

The jointing of the rock is nearly vertical, and in places the joints are continued into the overlying shale for 6 inches or more. The top of the rock is very irregular, and small patches of stratified rock remain in the hollows of the igneous mass, having been thereby protected from denuding agents. There is a little Boulder Clay at the surface, and under it the rock is ice-marked. At the west side of the quarry the altered shale contains fossils, such as *Productus*, etc., and is overlain by an encrinital limestone 3 inches thick.

West of this quarry I found in one place a vein of dolerite, 0·40 inch thick, running through the basaltic marginal portion of the mass of igneous rock.

At the points 10 and 11 on the sketch-map there are small exposures of basalt at a much lower level than the main mass of the igneous rock, and they are probably connected with the lower

[1] A. Geikie, Trans. Roy. Soc. Edinb. vol. xxix. (1879) p. 496.
[2] *Ibid.* pl. xii. fig. 12.

sheet which runs out from quarry 4 to localities 6 and 9. The rock is of the usual marginal character, and at locality 11 the top is ice-marked.

Between these lower basalts and the main sheet there is a considerable thickness of strata through which the Hosie's Limestone runs, and it has been worked by levels driven under the main sheet of igneous rock at the point marked 'Old lime-workings' on the sketch-map.

From near these lime-workings a thin sheet of igneous rock runs out past Sauchie Castle, and in the burn there an excellent section is exposed. There is at the top some 20 feet of dolerite, with the usual basaltic band or zone at the bottom. Below it there is some 7 feet of black shale, and below this again a band, 3 feet thick, of very hard rock which seems to be a black calcareous shale much altered and indurated; fossils can, however, still be distinguished in it. Below this bed come 6 feet of shale and then a sandstone, white and indurated, apparently, by the overlying igneous rock. This seems here to have affected the beds to an unusual distance below it. The underlying shales, sandstone, limestone, and coal do not appear to have been affected.

In connexion with the contact-alteration I may mention a microscope-section from a white altered shale at Cowden Hill in which there are numerous small collections or radial bunches of a white mineral which polarizes in brilliant colours. These collections in the contact-shale remind one of the spherulitic appearance of the contact-basalt.

I have in the preceding pages described contact-specimens from the bottom of the main mass of igneous rock at Sauchie Craig and from the outlying patch at Touchadam, also from the top of the main mass at Sauchieburn (locality 2 on the sketch-map) and from the top of minor sheets at localities 8, 6, and 4, and in all these cases there is seen to be a series of changes which take place as we approach the margin. The sequence seems to be somewhat as follows, beginning from the middle:—

1. Coarse-grained ophitic dolerite, which forms the greater part of the intrusive rock.
2. Fine-grained ophitic dolerite, say 10 to 20 feet from the margin.
3. Basalt, with very little augite and with hairs and rods of iron oxide in groups and scattered through the rock.
4. Basalt, with porphyritic plagioclase-crystals in a groundmass consisting of microliths of plagioclase and of iron—hairs and rods of iron oxide; no augite. This occurs as near as $\frac{1}{2}$ inch to the junction and as far as 5 inches from it.
5. Basalt, with porphyritic plagioclase in a grey groundmass, say $\frac{1}{10}$ to 1 inch from the margin.
6. Basalt, with porphyritic plagioclase in a hard groundmass, sometimes spherulitic—about $\frac{1}{10}$ inch thick on an average.[1]

[1] Compare Sir A. Geikie, 'Carboniferous Volcanic Rocks of the Firth of Forth Basin,' Trans. Roy. Soc. Edinb. vol. xxix. (1879) p. 496, pl. xii. fig. 12; Zirkel, 'Basaltgesteine,' Bonn, 1870, p. 92; Vogelsang, 'Die Krystalliten,' Leipzig, 1874, pl. xiii. fig. 1; Teall, 'British Petrography,' 1888, p. 166.

In all the contact-specimens above described we see evidence of rapid cooling towards the margin of the intrusive rock, whereas in the centre the magma obviously cooled down very slowly.[1]

In general appearance the Stirling dolerite is of a greenish-black colour, with white specks and occasional white and pink patches. There is always, or nearly always, a certain amount of pyrite scattered through it. There is frequently much calcite in veins, and in places the rock when altered becomes serpentinous. The rock has a certain amount of character of its own; thus, although I doubt whether, even assisted by the microscope, one could say whether a specimen came from the Abbey Craig, Stirling Castle, Sauchie, or Kilsyth, yet the dolerite differs more or less from most of the Scottish dolerites with which I am acquainted. Sir Archibald Geikie, however, observes that it is very similar to dolerite at Lindsay's Craig near Kirkliston, Crossal Hill near Dalmeny, and Muchraw near Torphichen.

A rather fine-grained variety of the Stirling rock from Kilsyth is figured by Mr. Allport, as I have already stated, and an account of the rock will be found in the Memoirs of the Geological Survey of Scotland, Sheet 31, 1879, p. 44; but I have seen no drawing that gives any very good idea of the coarse-grained dolerite of which the greater part of the Stirling rock consists. Perhaps the nearest is a figure of 'Dolérite labradorique de Laprabende-Caupenne, Landes,' given by MM. Fouqué and Lévy.[2]

In conclusion, I ought to thank numerous geologists who have given me assistance and encouragement in the study of igneous rocks in general. As regards the Stirling rock in particular I have several times consulted Mr. Teall when in doubt on various points; Prof. Bonney, with the greatest kindness, has looked through my microscope-slides and given me many hints, of which I have made full use in the preceding pages; and Sir James Maitland has accompanied me in much of my field-work, and has lent me several of the microscope-slides described in this paper.

Discussion.

Prof. Judd referred to the great interest of the new details given in this paper, and asked for further information concerning the mode of occurrence of the rock containing red felspars and the dark opaque junction-rocks with much magnetite.

Prof. Bonney said that the sections seemed in some respects analogous with the lower part of those at Arthur's Seat, and it was curious that the intrusive dolerite of Salisbury Craigs bore considerable microscopic resemblance to the intrusive masses of Stirling. He agreed with Prof. Judd that the glassy rock mentioned was probably only darkened with magnetite, and referred to other cases of felspars of a red colour both in dolerites and in veins in the

[1] Stecher, 'Contact-phenomena of some Scottish Olivine-Diabases,' Proc. Roy. Soc. Edinb. vol. xv. (1888) p. 160.

[2] 'Roches éruptives françaises,' 1879, pl. xxxvi. fig. 1.

same. It was interesting to learn that the Stirling dolerite was not a single mass, but a group of sills; and he thought that the careful study of these intrusive basic rocks was likely to be valuable.

Mr. Hudleston said that, thanks to the hospitality of Sir James Maitland, he had seen a portion of the district described by the Author, and was glad to confirm, so far as his knowledge extended, the relations of the dolerite to the adjacent strata. He did not quite gather how far the rock was to be regarded as intrusive, or, if intrusive, at what period.

Sir James Maitland said that he knew the district, and thought that the paper would throw light on the conditions under which basalt cooled. In Milnholm Quarry the basalt showed a fine-grained structure at the upper and lower edges, while as the position retreated from one or other the size of the grain increased. The general dip of the basalt is 1 in 10, while that of the strata is 1 in 11; thus the basalt cuts very slowly through the stratified rocks and is clearly intrusive in the Coal Measures, for the same bed can be traced and junction-sections obtained with the upper and lower surfaces of the sheet.

Mr. Rutley asked the Author for further information concerning the occurrence of the tachylyte. Skeleton-crystals of magnetite, such as the Author described, were not uncommon at or near the margins of intrusive rocks, but in some cases, where the vitreous selvage was poorly developed, spherulitic structure sometimes occurred unaccompanied by skeleton-crystals of magnetite.

The Author, in reply, thanked those present for the kind way in which they had received the paper. He had no doubt that the Stirling dolerite was an intrusive rock, but all one could say as to its age was that it was newer than the Carboniferous Limestone Series, and older than the long faults and dykes which cut it.

33. Notes *on some* Railway Cuttings *near* Keswick.

By J. Postlethwaite, Esq., F.G.S. (Read May 8th, 1895.)

[Abstract.]

Several cuttings have recently been made on the Cockermouth, Keswick, and Penrith Railway, chiefly through drift, though some occur in the Skiddaw Slates, and in one case a diabase dyke (much decomposed) was met with. It is similar in character to a rock exposed about ¼ mile west of Troutbeck.

The Author describes the drifts as blue clay beneath, and brown clay above, and considers that these two clays were produced during two separate periods of glaciation, with no long interval between. In some places near Keswick water-borne gravel may be seen surmounted by blue clay; this gravel is considered by the Author to be of fluviatile origin. A section at Keswick Station is described; it is 130 yards in length, with a slight break in it, 50 yards of the western end being cut back 9 feet to the north. At the point where the break occurs, and for 17 yards eastward, some beds of current-borne materials take the place of the lower part of the blue clay. There is a bed of a very fine brown sediment 1 foot thick; above it is 2 feet of fine sand, and above that a bed of coarse gravel and pebbles, which is succeeded by blue clay of the usual type. The whole of these beds dip south-west, at an angle of about 9°.

The Author has searched both blue and brown clays diligently for shells, but hitherto without success.

Discussion.

Mr. Marr said that he knew the igneous rock occurring near Troutbeck Station; it was one of the most rotten rocks in the district. His examination of the brown and blue clays described in the paper led him to infer that the 'brown clay' was merely the weathered condition of the blue clay. With regard to the gravel-deposits mentioned in the paper, he would say little, but each gravel-deposit in the district required explaining, for the various gravels had very different methods of origin.

Dr. Hicks was also inclined to believe, from evidence in North-west Middlesex, that much of the brown clay was merely weathered Chalky Boulder Clay, and this had often been mistaken for London Clay; indeed large areas supposed to show on the surface true London Clay were entirely mantled by this weathered Boulder Clay.

Dr. Hinde also spoke.

34. Ice-plough Furrows *of a* Glacial Period.

By W. S. Gresley, Esq., F.G.S. (Read April 3rd, 1895.)

[Abstract.]

The furrows described in the paper occur in the Coal-Measures of North-western Leicestershire. The Author considers that they were formed about the time of the Glacial Period by floating ice.

35. Geological Notes *of a* Journey *round the* Coast *of* Norway *and into* Northern Russia.

By G. S. Boulger, Esq., F.L.S., F.G.S. (Read May 22nd, 1895.)

[Abstract.]

The Author accompanied the Jackson-Harmsworth Polar Expedition as far as Archangel, and returned by way of the River Dvina. His observations relate mainly to four points:—the origin of the foliation of the Norwegian gneiss; the question of raised beaches on the North-western coast of Norway; the boulders and boulder-formation of Northern Russia; and the Trias of the Dvina valley.

Between Christiansund and Tromsö the Author was struck with the wide-sweeping folds of the foliation-planes of the gneissose rocks, which appeared to him more readily explicable on a theory of dynamo-metamorphism of rocks originally in part igneous, than by any process of diagenesis. He notes that the terraces observed in the transverse fjords would be perfectly explained by the formation of ice-dammed lakes, though the terraces of the Gulf of Onega seemed less dubious raised beaches than those of the North-west of Norway. He confirms the views of previous writers that many of the boulders of the boulder-formation of Northern Russia are of Scandinavian origin. The beds on the Dvina consist of sands and loams, often coloured red, with bands of alabaster and anhydrite. The strata are horizontal or inclined at a low angle. North of Ustyug Veliki the strata are marked as Permian on the Russian maps, and those to the south as Trias, but the Author saw no perceptible break in the succession.

Discussion.

Col. Feilden remarked that, so far as his experience went, raised beaches and other proofs of secular elevation of the coasts of Northern Norway were a striking feature, and he felt surprised how they could be overlooked.

Prof. Bonney asked whether the Author had carefully collected and studied specimens, for he doubted, in so difficult a problem, the value of observations founded on superficial inspection. Also he failed

to understand why the intercalation of crystalline rocks, simulating stratification, described by the Author, should be any proof of dynamo-metamorphism. As regards raised beaches and sea-marks, he entirely agreed with Col. Feilden. They abounded in the fjords of the more southern part of Norway, and almost everywhere to the north. As had been often described, their height above the sea varied even in the same fjord, and they contained sometimes marine shells. If they were due, in the north, to lakes dammed up by ice, where was the ice-sheet formed, and how was it, if so great a mass of ice existed, that the Norway valleys were not filled with glaciers instead of water?

The Author, in reply, regretted that he had been unable to land in Norway. The authenticated occurrence of marine organisms in raised beaches would be conclusive; but slight differences in their levels might be misleading. He saw various moraines, but no well-marked beaches along the main coast. He inferred dynamo-metamorphism from the interstratification of limestone with gneiss and a granitoid rock, as in the district round Christiansund, where the whole series had been folded together.

36. *On the* SHINGLE-BEDS *of* EASTERN EAST ANGLIA. By Sir HENRY H. HOWORTH, K.C.I.E., M.P., F.R.S., F.G.S. (Read April 24th, 1895.)

THESE well-known beds have been variously named the Westleton Beds, the Bure Valley Beds, and Pebbly Beds. Their centre of distribution and focus, however, is near Southwold, and they might well have been called the Southwold Beds. The following remarks are limited entirely to the actual beds of pebbles as they are displayed in Eastern Norfolk and Suffolk, where they have been studied and described by Prestwich, Whitaker, and others.

First a few words about the recent strand. This consists of shingle precisely like that in the cliff-sections. A fact about it which has not apparently been hitherto noted is that this shingle on the beach travels in and out, not with the wind, but against the wind. Thus during easterly gales the whole strand is free from stones, while in westerly winds the pebbles are again piled up. So far as we know, there is no shingle like this anywhere on the bed of the German Ocean. Wherever it came from, therefore, it cannot have come from the east. As a matter of fact, it is obviously the product of the disintegration of the cliffs.

The cliffs on this coast are really the truncated ends of a series of promontories projecting from the main plateau of the county and fringed round by low land. It is from these truncated promontories, which are capped with similar pebbles, and from these alone, that the shingle on the beach has been derived, and not from a general erosion of the coast.

It seems plain, from their present contour and from the fact that the sea is everywhere encroaching on this coast, that these promontories were quite recently intact, and not cut back as we now see them. This is again shown by the fact that the pebbles on the strand are virtually identical in size with those in the cliffs. If they had been triturated for any length of time they would have been ground into gravel of smaller stones.

It is therefore evident that the strand is quite a recent one. Before the cutting back of the promontories took place the whole strand was doubtless sandy and muddy, and the high tides, not having such powerful chisels and hammers combined, as are formed by shingle-beds, would not be such powerful erosive agents, so that it seems to follow that the present rate of erosion of the cliffs is much more rapid than it was in former times.

Let us now turn from the daughter-shingle on the beach to the mother-shingle on the cliffs. Its composition has been described by Prof. Prestwich and others, and I cannot improve on their description, which I need hardly say has been confirmed by every observation that I have been able to make. Prestwich says of it, 'The shingle

is composed essentially of quartzose sands full of flint-pebbles, almost as much worn and as numerous as in the Lower Tertiary sands of Blackheath. With these are mixed a good many white and rose-coloured quartz-pebbles, 2 pebbles of lydian-stone, 3 large flattened pebbles of light-coloured quartzite, 4 rolled and worn fragments of Lower Greensand chert.' Of these materials the first forms the great bulk of the shingle, the rest of the contents being sporadic and scattered.

The first thing that will be obvious to any one who examines this Southwold or Westleton shingle is the fact that it is not in place,—that it is in every sense a true Drift. Its component parts were not put together as we find them, nor were they ground and polished on the spot. The larger part of the pebbles—namely, the flints—are foreigners, and strangers to the locality where we meet with them. The flints, no doubt, were derived from Chalk somewhere, but the Chalk in this part of England is buried deep down under beds of Tertiary age, and its flints are absolutely protected from any possible intrusion of a denuding force, whatever it may have been. So with the chert. It is quite impossible to suppose that these beds of shingle, lying as they do, sometimes on Crag-beds, sometimes on London Clay, have derived their flints from horizons in which these materials are conspicuously absent.

The next question is, whence has this drift come? If we are to get a hint of the place whence the shingle has come we must first examine its composition. If we do so examine its contents, we shall find that we can separate them into two classes of materials. In one class I would put the smoothed flints and some of the green quartz-pebbles, and in another the rest of the ingredients.

If we examine the flints and quartz-pebbles apart from the other material, it is impossible to avoid the conclusion that they are essentially the same in character with the pebbles in the beds of Eocene-shingle age found elsewhere. This was long ago urged by Prof. Prestwich and others, and it seems as plain as can be that this so-called Westleton Shingle is essentially a disintegrated bed of Eocene gravel dating either from the period of the Plastic Clay series, of which typical beds are found *in situ* at Woolwich and Reading, or from the same horizon as the Blackheath Beds.

Turning from the flint-pebbles to the other ingredients in the shingle, I cannot quite agree with Prof. Prestwich in his conclusion. He connects certain light-coloured quartzite-pebbles in the shingle with similar pebbles found in Belgium, while he brings the fragments of ragstone directly from the Greensand series of Kent, and on the strength of this brings the shingle itself from the south and east. Now I believe myself that these other ingredients, whatever their ultimate origin, were directly derived either from the Plastic Clay or the Red Crag. Prestwich states that he has found the large pebbles of white or light-coloured quartzite occasionally in the shingle-beds of the Woolwich and Reading series. These, as well as the other pebbles, may, however, have come from the Red Crag, where they actually occur, as was long ago pointed out by Prestwich

himself. Thus he says, 'We have evidence, however, of a similar southern drift in the presence of chert from the Lower Greensand, and quartz, quartzites, and other such specimens either from the Ardennes or the Rhenish provinces, at the base of the Red Crag.'[1] And he elsewhere tells us how in a pit at Trimley, near Felixstowe, he had himself found 'subangular fragments of Lower Greensand chert, a large fragment of red granite, and fragments and pebbles of siliceous sandstones.'[2] He elsewhere says that this siliceous sandstone is what he afterwards called 'quartzite.' Again, he says (in his 'Geology') 'The basement-bed of the Red Crag contains large quartzite-pebbles, fragments of Lower Greensand chert, etc.'

We need not, therefore, go to Belgium or very far away to explain the Westleton Shingle. Those ingredients in it which have been referred to a far-travelled or foreign origin are, in fact, found readily available in the Red Crag of East Suffolk.

This conclusion leads us to another. The shingle which we are discussing contains shells in certain places. These shells have never been found in the corresponding beds inland, and only occur in certain localities in the eastern parts of East Anglia. Upon this every one is agreed. As Prof. Prestwich says, 'they are found only in that part of the beds found on the seaboard of the Eastern Counties.' Thus they occur, as every one knows, at and near Southwold, at Henham, and in the Bure Valley.

I venture to propound a heresy in regard to these shells. There have been few more suggestive and important conclusions arrived at in recent years than that which was first suggested by, I believe, Mr. Horace Woodward, and in which Mr. Clement Reid concurs, that all the shells in the so-called 'Glacial Beds' of East Anglia are derivative and are not *in situ*. I believe the same thing to be absolutely true of these shingle-beds. Where I have seen shells in connexion with them they have always seemed to me to have been directly derived from the Crag. They are either contained in pockets of Crag sand or in close contact with Crag-beds, and, as is well known, the species of shells found in these beds are all Crag shells. Mr. Whitaker has described 24 species from this shingle in his excellent memoir on the Southwold Shingle, every one of which is derived from the Crag. Similarly, in the Bure Valley, the shells found in the sands which occur with the shingle are identical with those in the Weybourn Sands, another Crag deposit.

The view here maintained has, in fact, been hinted at by Prof. Prestwich, although he has not definitely adopted it. Thus he says, 'I am not quite satisfied that these shells, or at least all of them, belong to the Westleton Beds.' At Henham casts and impressions of shells were found in an iron-concreted portion of the shingle, while at the bottom of the pit actual shells were found. At Southwold the shells occurred in a lenticular mass, 6 inches thick and about 5 feet deep, in a cutting 7 feet in depth, and in another small

[1] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 114, note.
[2] *Ibid.* vol. xxvii. (1871) p. 326.

patch about 12 yards northward. It appears to me, however, possible that some of these shells may belong to the Upper Crag (the Chillesford Sands); for the Chillesford Clay has been much denuded, so that the pebble-beds often come into juxtaposition with the Upper or Fluvio-Marine Crag. A little north of Southwold the cliff-section, in fact, shows the Pebbly (Westleton) Beds in contact with yellow sands of this age, owing to the removal of the Chillesford Clay. It may be, therefore, that the lower part of the sections belongs to the Crag, or that the shells are derived from it. 'Mr. Whitaker mentions that the Chillesford Clay is wanting in places near Southwold, probably having been cut off by the Pebbly Beds. It was wanting also in the Southwold well, where the underlying Crag was fossiliferous.' [1]

On the other hand, Mr. Horace Woodward, on the strength of these fossils, which, as I have said, I believe to be derivative in the shingles, classes the Bure Valley Beds with the Upper Crag, and treats them as a part of the Norwich Crag series.

It is curious that in the case of certain beds at Sudbury, in the south of Suffolk, where Mr. Whitaker has found *Purpura lapillus* var. *crispata*, with casts of some uncertain species, including *Natica*, *Cardium*, and *Mytilus*, and some coprolites, that he should class the beds with the Crag with a query, and that Prof. Prestwich, having originally classed them with the Red Crag, afterwards classed them, on the ground of position and composition, with the Westleton Beds; but he adds, 'The fossils and the coprolites may have been derived from the Red Crag; for the beds under the Westleton Shingle are, as will be shown further on, often greatly eroded. Or we may have here a remnant of Red Crag at the base of sands and gravel belonging to the Westleton Series.' [2]

I am, therefore, of opinion that the shells which are found in certain limited localities only in the shingle-beds, generally at their base and in close contact with Crag-deposits, are in every case derived and *remanié*, just as the shells in the so-called 'Glacial Beds' are, and that they in no wise mark the horizon of the shingle, and we have consequently no warrant for calling these shingles marine beds. The shells, like the pebbles of ragstone and quartzite, are apparently derived directly from the Crag.

This conclusion is an important one, and it does away with some of the difficulties which have attended Prof. Prestwich's main conclusion in the eyes of many students. Sir A. Geikie has raised objections to these shingles being marine beds. Mr. Monckton, Mr. Herries, and others have also failed to find evidence of marine action in the Essex gravels correlated with the Westleton Beds.

On the other hand, the fact does away with conclusions like that embodied in the following sentence:—'It is obvious, from the fossils found in it in Norfolk and Suffolk, that the Westleton Shingle is a marine Drift, the absence of shells in its inland range being no doubt in great measure owing to decalcification. Even in Suffolk,

[1] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 92, note.
[2] *Ibid.* p. 130.

where the beds are more protected, it is rarely that anything more than casts are found,'[1] and also the conclusion that this shingle was laid down in a sea extending as far as the North of Belgium.

It seems to me strange, if such complete decalcification took place in other areas, that it did not also remove the shells in East Anglia, and the conclusion which I have presented is not only in agreement with the facts, but simplifies the problem greatly.

The shingle is a true drift, and when it was driven over the Crag-beds of East Anglia and tore up their surfaces, as we can see them torn in many places on the cliffs, it took up in some limited localities portions of the Crag-beds containing adventitious stones, in some cases pockets and layers of sand, and in some cases also Crag shells, and it is a mistake to fix any special horizon for them by means of these shells or stones.

The next question is, where were the Eocene beds whose disintegration has given rise to the shingle? We can hardly doubt that Eocene beds cover the Chalk in all the eastern part of Norfolk, Suffolk, and Essex, and it would seem almost certain that they once covered the Chalk as far west as the Chalk Escarpment, including West Norfolk and Suffolk, Cambridge, and Hertford, with continuous beds. Also that the various shingle-beds, from the Bure Valley to High Beech in Essex, which have been correlated together as the Westleton Beds or the Pebbly series, are the result of the disintegration and denudation of the former Tertiary covering of this Chalk area, and that the pebbles have drifted from the west eastwards.

The next point is, what was the force that moved this gravel from its original position farther west and drove it over the Crag-beds of Eastern East Anglia? Spreading it out irrespective of the contour of the country, and notably on its higher ground, piling it up in some places to great depths, and doing this in most singular fashion, as for instance on the hill on which Southwold itself stands.

Some brave men who see ice everywhere, and who have apparently never troubled themselves to enquire what ice as a physical agent can actually do and what it is doing, have attributed the distribution of this shingle to land-ice. How a glacier could possibly move about with sheets and masses of gravel made up of loose and slippery stones, and deposit them in this fashion I know not. So far as I know, the shingle is everywhere a true shingle. It contains no far-travelled stones at all; it contains no large stones at all; and the only piece over 1 foot in diameter which has ever been discovered in it is a lump of micaceous quartzite found by Mr. Whitaker at Easton, wedge-shaped, and measuring $13 \times 13 \times 19\frac{1}{2}$ inches. This seems to me to have been undoubtedly derived from the Crag. The shingle-beds are often rudely stratified and false-bedded, a condition of things inconsistent with deposition

[1] Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 146.

by ice. They contain in places fragile shells, but not a scratched stone, not a foreign boulder, nothing of the kind, and there seems to me to be absolutely no reason, except a mere wanton devotion to *a priori* theories, to justify the intervention of ice in any form to explain these shingles and their distribution.

It seems just as wanton to speak of these shingles as the result of fluviatile action. They occur, not only on the plateau, following its meandering contour, but down the sloping sides of the hills to the bottom and lower part of the valleys; and the way in which they mantle the country makes it plain that when they were distributed the country had its present contour. If so, how is it possible to speak or think of rivers in connexion with the distribution of beds of shingle like these, which are formed of stones much larger than ordinary gravel; which no ordinary river could move at all; which are not deposited in old channels or river-beds, but spread out in vast sheets, in many places piled up to great depths, and arranged quite irrespectively of the drainage of the country? It seems to me that we can explain these beds only by a tumultuous diluvial movement, a view supported by some great names among the older geologists. Such a movement possibly broke up and stripped off the old Tertiary gravels from the Chalk, swept them along over the Crag-beds, tore the latter up, denuded them in many places, and mixed their pebbles and shells with the moving mass. Such a tumultuous current could alone, it seems to me, move these gravels of abnormally large pebbles, could alone mix them and distribute them in this fashion, and then leave its traces in the actual internal arrangement of the beds, whose false-bedding in some places and tumultuous arrangement in others point to a more or less violent cause.

There still remains a polemical issue upon which I have not said anything: namely, the exact horizon of these shingles. On this point I should like to reserve what I have to say until I have discussed the representatives of these shingles of Eastern East Anglia further inland, and the problems connected with that much more important deposit the 'Great Chalky Clay,' which you will perhaps allow me to do on another occasion. At present we are committed to nothing on this thorny subject, except that the East Anglian Shingle overlies the Crag, and generally underlies the 'Great Chalky Clay.'

Discussion.

Prof. T. McK. Hughes, referring to certain specimens of ballast exhibited by Sir Henry Howorth, said that the ship to which they belonged was the 'Katie Hannah,' an English vessel which had been sold to Norwegians, had taken in ballast in Norway, proceeded to Malmö, from which she sailed with a cargo of timber, but was driven ashore north of Hunstanton in the winter of 1893–4. A great heap of ballast was lying beside the vessel on the sand when first he saw it, but she was subsequently blown up, and now (April 1895) there is no trace of the vessel or the ballast, except a few projecting pieces

of iron and a deep hollow like a dock, which is always full of water, deep beneath which the ballast lies buried. Some of the ballast had been taken by fishing-boats, and from a heap of this on the beach south of Hunstanton the specimens exhibited by Sir Henry were procured. The whole of the ballast had been offered for metal to the road-surveyor, but he declined it on the ground that it was not worth the great expense of haulage over the soft sand between the wreck and the shore. The speaker was informed that in some cases such ballast had been disposed of at Lynn for road-metal or paving, and he strongly suspected that it was carried in barges far inland for similar purposes.

With regard to the subject of Sir Henry's paper, he agreed with him that most of the material of the shingle of East Anglia had drifted from west to east, and that none of it could have been derived directly from Belgium in Pleistocene times. He thought that gravels of very different age and origin had generally been classed together; that the constituents had been handed on second, third, or fourth hand from various older beds—the white quartz-pebbles from the Carboniferous; the liver-coloured quartzite from the New Red; the lydian-stone from the Lower Greensand (from which also many quartzites, etc. were derived); small flint-pebbles from the lower part, and larger flint-pebbles from the upper part, of the Lower London Tertiaries; and rocks and fossils from Belgium second-hand from the English Crags.

Mr. H. B. Woodward, while agreeing with the main contention of the Author that the Westleton Shingle was derived largely from Eocene pebble-beds, thought that some of the stones might have come from the Norwich Crag and Forest Bed Series. Mr. Clement Reid had noted quartzites, etc. in the Forest Bed Series ('Geol. Cromer,' pp. 55–57), and some of these rocks might have travelled from the Belgian area.

He could not support the notion that the shells of the Bure Valley Beds were derivative. The Westleton Beds (of Westleton) were, in his opinion, of Middle Glacial age.

With regard to the diluvial action advocated by the Author, he observed that Norfolk geologists sometimes spoke of the 'Flood Gravels' that succeeded the great ice-sheet which formed the Chalky Boulder Clay; and perhaps the diluvial movement suggested by the Author might be attributed to the melting of ice which formed the Lower Boulder Clay or Cromer Till.

Mr. Monckton thought that the evidence brought forward by Prof. Prestwich did go a long way to show that the Westleton Shingle, and the scattered patches of gravel in the South of England which contained numerous white quartz and light-coloured quartzite-pebbles, belonged to an older period than the Northern Drift of the same area, with liver-coloured and reddish quartzite-pebbles. He felt keenly the difficulty in deciding as to the origin of the various gravels, the evidence being most imperfect and scanty. He had listened to the paper with great interest.

Mr. R. S. Herries asked whether the Author correlated the so-

called Westleton Beds inland with those of Southwold? If so, whence did he derive the small white quartz-pebbles which occur so abundantly in those beds? and if from the west, as he (the speaker) understood the Author to say, how did the latter account for the increase of the material as it got farther from the source of supply?

Dr. G. J. Hinde was desirous of knowing whether the Author had been able to discover the rocks from which the white quartzites had been derived originally. He had been much surprised to hear the formation of these beds seriously attributed to cataclysmal action.

The Rev. H. H. Winwood, after some preliminary remarks respecting the 'pluvial' theory, formerly adduced in connexion with the deposition of the drift, said that the source of the white quartz had still to be traced. After hearing Prof. Prestwich's paper on the Westleton drift, he had found these characteristic pebbles about the size of marbles, mixed up with lydian-stones, but no liver-coloured quartz, on the Oolitic plateau (600 feet O.D.) on the south side of Bath, immediately below the turf.

The Author replied.

37. *The* Chalky Clay *of the* Fenland *and its* Borders: *its* Constitution, Origin, Distribution, *and* Age. By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S. (Read June 19th, 1895.)

[Abstract.]

The distribution of the Clay (so often termed Chalky Boulder Clay) is noticed, and it is stated that it is surrounded on all sides by country occupied by different deposits, being mainly separated from the sea on the east and north-east by sandy and pebbly materials, while on every other side it is clearly and sharply defined. The paucity of foreign stones is noted as compared with natives, and the similarity of the matrix of the Chalky Clay to the material of the older deposits of the neighbourhood. The Author maintains that the contents of the Clay indicate movement of material from west to east in some places, as shown by Jurassic fossils in the East Anglian Chalky Clay, and from east to west in others: in fact, that movement took place in sporadic lines diverging from the Wash and the Fens. He appeals to the amount of disintegration that has taken place to furnish the material for the Clay, the shape of the stones in the Clay, and the distribution of the Clay itself, as evidence against the action of land-ice or icebergs, maintaining that there is no evidence of submergence at the time the Clay was formed; and criticizes the attempts made to explain the formation of the Clay by water produced by the melting of ice.

The Author believes that the denudation of the Fen country which produced the great mass of the Chalky Clay with most of its boulders was coincident with and caused by the bending and folding of the Chalk of Eastern England, which took place after the deposition of the Crag beds, and that during the period of folding a great depression was formed round the Wash, into which the water rushed from the North carrying débris and mixing it with clays; this, rushing into what was virtually a *cul-de-sac*, dispersed and scattered its load in all directions.

38. *On a* Human Skull *and* Limb-bones *found in the* Palæolithic Terrace-gravel *at* Galley Hill, Kent. By E. T. Newton, Esq., F.R.S., F.G.S. (Read May 22nd, 1895.)

[Plate XVI.]

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I. Introduction.

At a time when so much attention is being directed to the implements made by Palæolithic Man, the discovery of a human skeleton in the Palæolithic gravels of this country cannot but awaken much interest. The remains which form the subject of the present communication have been submitted to me for description by Mr. Robert Elliott, of Camberwell, whose enthusiasm as a collector of flint-implements and other antiquities is well known to many of us, as is also the fine collection of these relics which he has with much labour brought together. It was in the year 1888, on one of his journeys in search of 'implements,' that Mr. Elliott discovered parts of a human skeleton in the gravel yielding Palæolithic implements, which, at a height of about 90 feet above the Thames, overlies the Chalk at Galley Hill, Northfleet. The particulars of this discovery are given in a letter from Mr. Elliott, which will be found at p. 518. The interest of the discovery has seemed to me sufficient to justify a full account of it being placed on record, so that all attendant circumstances may be known, and everyone interested in the matter placed in a position to draw his own conclusions as to the age of these human remains.

II. Description of the Remains.

The portions of the skeleton which have been recovered are: a large part of the skull, wanting the facial bones; the right half of the lower jaw still retaining the grinding teeth; both femora and parts of both tibiæ; a clavicle, wanting the extremities; the shaft of a humerus; fragments of the pelvis and sacrum, as well as some pieces of ribs. All the bones are much decayed and denuded, while their outer surfaces are marked all over by vermiform depressions, such as are generally thought to be the

result of close contact with the rootlets of growing plants. When first exhumed, the bones were exceedingly soft and fragile, and, in spite of the care with which they were handled, were all much broken in the process of extraction from the matrix; it was necessary, therefore, to treat them with gelatine and allow them to dry and harden before they could be joined together and rendered fit for study. The presence of the last true molar, or wisdom tooth, with the crown somewhat worn, shows that the skeleton belonged to a fully-grown adult, though probably not an aged individual.

The Skull (Pl. XVI.)—The calvarium was fortunately less broken than the long bones; it is evident, however, that in drying it has become twisted somewhat; but its general characters are clearly shown. The base and facial portions of this skull are wanting, as well as much of the left side; the right side, however, is more perfect, the outer part of the orbit, with the maxilla and jugal bones, being all that is really absent. A portion of the foramen magnum is preserved, with sufficient of the supraoccipital bone to show the form of the under and back parts of the brain-case.

The most striking features of this skull are its extreme length (205 millim.[1]) in proportion to its width (about 130 millim. ?), the complete obliteration of the coronal, sagittal, and lambdoidal sutures, both internally and externally, and the prominence of the supraciliary ridges. The extreme narrowness of the cranium is best seen when viewed from above; but this peculiarity is somewhat exaggerated by the distortion which the skull has undergone, the right temporal bone, and the parts posterior to it, being pushed over towards the left side; and besides this, parts of the left side are wanting. The greatest width of the skull is low down, near the mastoid region, but its imperfections prevent the exact width from being measured.

The walls of the cranium are in most parts very thick, the middle of each frontal measuring as much as 12 millim. The supraciliary ridges are very strongly developed, especially at their inner part, although now in a denuded condition; probably they were never so prominent as in the famous Neanderthal calvaria. The frontals are fairly full, and the forehead therefore only moderately receding. The highest point of the skull is in the fore part of the parietal region. The temporal ridge is not strongly marked, but extends abnormally high up on the side of the skull. The right parietal is somewhat inflated at its anterior and lower part, and this inflation is continued on to the adjoining lower part of the frontal, causing a prominent stephanic region. Towards its hinder part likewise the parietal is prominent. The occipital bone forms a well-marked boss or probole at the back of the skull, its upper part being directed well forward as well as upward, and this portion, together with the median and hinder ends of the parietals, forms a distinctly flattened area.

[1] Dr. Garson has kindly gone over the measurements with me, and where, through imperfection of the specimen, we differed to the extent of a few millimetres in our estimate, the intermediate measurement has been adopted.

TABLE I.—MEASUREMENTS OF VARIOUS HUMAN SKULLS IN MILLIMETRES.

	CIRCUMFERENCE.		LENGTH.		BREADTH.		BREADTH-INDEX.		HEIGHT.		HEIGHT-INDEX.	
		AVERAGE.		AVERAGE.		AVERAGE.		AVERAGE.		AVERAGE.		AVERAGE.
Galley Hill	540	...	203 [1]	...	130 (?)	...	64 (?)	...	137 (?)	...	674 (?)	
Spy, *ex Fraipont*	580–590	...	200	...	140–150	...	70–74					
Neanderthal, *ex Fraipont* ...	571	...	200	...	144	...	72–74					
Long Barrows, *ex Thurnam* .	495–556	541	180–207	196	130–147	140	63–77	715	124–155	142	680–780	730
Caves, Perthi Chwareu, *ex Busk & Dawkins*	470–597	508	170–192	179	127–147	140	74–80	765	137–147	142	710–846	784
Basque, *ex Thurnam*	482–548	523	165–195	184	125–150	140	71–83	760	122–145	137	69–80	740
Borris, Ireland, *ex Huxley* ...	.....	...	203	...	150	...	737	...	137	...	680	
Engis, *ex Dawkins*	521	...	196	...	137	...	70					
Cro-Magnon, *ex Reliq. Aquit.*	557	...	200–203	...	152	...	748	...	140	...	700	
Round Barrows, *ex Thurnam.*	491–553	536	165–201	184	137–165	150	74–89	810	127–158	142	68–83	770
Trou de Frontal, *Dawkins* ...	547	...	175	...	142	...	811	...	...	...	704	
Eskimo, *ex Flower*	481–558	...	169–201	...	125–145	...	661–787	722	125–147	...	692–793	737
Australian, *ex Flower*	472–547	...	167–198	...	120–145	...	680–772	710	118–143	...	635–826	715
Fijian, *ex Flower*	486–550	...	175–203	...	117–134	...	619–714	663	132–147	...	724–785	741
Negro, *ex Flower*	466–545	...	166–192	...	122–150	...	643–811	733	124–145	...	670–801	738
Melanesian, *ex Thomas*	527	...	202	...	125	...	619	...	131	...	649	

[1] This measurement is taken from the ophrion, so as to correspond with others given in the table.

The circumference of the cranium is 540 millim., and its length, measured from the ophrion to the farthest point of the occipital prominence, is 8 inches or 203 millim. The breadth cannot be certainly measured, as the left side is wanting in the lower parietal region, where, as the right side shows, the greatest width of the skull is situated. After several attempts to take this measurement, and making due allowance for missing parts, Dr. Garson and I came to the conclusion that the breadth could not have been more than 132 millim., and was probably not less than 128 millim. (medium 130 ?); the breadth-index is, therefore, as nearly as can be measured 64 (?), the skull being extremely dolichocephalic, as indeed is obvious from a general inspection. It may be thought that the skull has undergone lateral compression; but, if this were so, an extension would have taken place in the direction of its height, and this is found not to be the case. The basion being absent, the exact height cannot be measured, but as the hinder margin of the foramen magnum is preserved, this has been taken as a fixed point; and by comparing, in other skulls, the relation between the bregmatic height and the height above the hinder margin of the foramen, a proportion between these two measurements has been obtained, which, being used in the present instance, gives approximatively a height of about 137 millim. for this Galley Hill skull, and consequently a height-index of about ·674. The frontals are narrow immediately behind the maxillary process, and could not have measured much more than 100 millim. when perfect.

Lower Jaw.—The right half of the mandible is preserved, but not in a very perfect condition; the angle and articular process are wanting, having apparently been dissolved. The entire surface of the bone is also much denuded, and so much of the ascending ramus as is preserved is very thin. Even the fangs of the teeth have been partially dissolved, the enamel now standing out prominently from the necks, especially on the inner aspect. The chin is still moderately prominent, although its extremity has been broken away. The alveoli for the incisors are broken down, and the deepest part of the ramus in its present condition is below the interval between the two premolar teeth, where it measures 31 millim. Below the hindermost molar the depth of the ramus is 25 millim. Just below the hinder premolar there is a large vascular foramen about 10 millim. from the lower margin.

The symphysial portion of the jaw is preserved, but the incisors and canines are wanting. On each side of the symphysis the alveolar border is broken; but while portions of the alveoli for the two outer incisors are preserved, there are no traces of the alveoli for the two median incisors, which must have been either very short or else lost during life, and the alveoli filled up by bone.

The alveolus for the right canine is larger than that for the first premolar, and its extreme depth from the inner margin is 14 millim.

The first premolar has a higher crown than the second, but is otherwise a little smaller. The first true molar is just a trifle larger than the second, as will be seen by reference to the table of measure-

ments below, and the third true molar is as large as the first. The upper surfaces of all the teeth, molars and premolars, are much worn by attrition, presenting a nearly flat surface (Pl. XVI. fig. 2); and in each tooth the enamel has been worn through so as to expose in each premolar one area of dentine, in the first true molar four rather large areas, in the second four smaller ones, and in the third or last molar two, perhaps three, such areas. The enamel of the crowns seems to be very thick, but this is due in some measure to the condition of wearing.

Table II.—Comparative Measurements of Galley Hill and other Remains in Millimetres.

	Galley Hill.	Spy.	Eskimo.	Fijian.
Teeth:				
Front molar tooth, width from before backwards	11·5	10 to 11·5	11·5	12·5
Front molar tooth, thickness from side to side	10·8	10·5 to 11·5	11	11·5
Second molar, width	11	10 to 11	10·5	12·3
„ „ thickness	10·5	10 to 11	10·5	11·5
Third molar, width	11·5	11 to 12	12	12·5
„ „ thickness	10·8	11 to 12	11	11
Femur, length	421	420		
„ diameter, antero-post.	25?	29		
„ circumference	90?	90		
Tibia, length	?	320		
„ circumference	85	90		
„ mid. longitudinal diam.	32·5	33	31·2	
„ „ transverse diam.	24	24	24	

The femora are both preserved, but are much damaged; that of the left side is the more perfect (Pl. XVI. figs. 6 & 7), although its greater trochanter and part of the head are broken away; the shaft is so much denuded, especially in the middle, that its diameter cannot be accurately measured: it seems to have been about 30 millim. from side to side and 25 from back to front, excluding the linea aspera. The distal articular condyles are denuded externally and internally, so that their width is uncertain; their antero-posterior extent is found to be 62 millim. The greatest length of the femur is about $16\frac{1}{2}$ inches (419 millim.). The shaft is nearly straight, being only slightly convex forwards. The articular head is comparatively large, its vertical diameter being 48·5 millim. The shaft and neck of the bone are rather flattened from before backwards; but the long axes of these two portions seem to be at the usual angle with each other. The upper part of the shaft, however, is twisted upon itself, so that the neck and head are turned more forward than usual; the exact amount of this torsion cannot be measured, on account of the imperfection of the distal

condyles. The lesser trochanter is moderately developed, and there is a strong linea aspera. The distal condyles could not have been unusually large, and certainly did not project abnormally either forwards or backwards.

Parts of both tibiæ are preserved; they are neither of them in a condition to give any idea of their length, although enough of the shaft of the right one is preserved to show that it was small and has no tendency to platycnemism (Pl. XVI. fig. 8). At about 40 millim. below the nutritive foramen its antero-posterior diameter is about 31 millim. and its transverse diameter 24 millim. The hinder surface of the shaft is fairly rounded, and does not project to any unusual distance behind the level of the interosseous ridge: the proportion being in front of this level 22 millim., behind it 9 millim. (=244 to 1000). The interosseous or fibular ridge is well marked, and there is a broad longitudinal depression in front of it. The anterior edge of the bone is sharp.

The shaft of the right humerus is preserved, and is remarkable for the flattening of its inner surface, as well as for the extraordinary development of its anterior oblique ridges; these striking characters, however, may be fairly matched among the series of humeri preserved in the Museum of the Royal College of Surgeons. It is evident that the corresponding muscles were well developed.

There is a stout clavicle, which calls for no special remark, except that the ridges and rugosities are strongly marked.

The fragments of the pelvis and sacrum are too small to exhibit any useful diagnostic characters.

III. The Galley Hill Skeleton compared with other Races.

1. British Fossil Human Remains.

Human bones have frequently been found in British caves; they are, however, with few exceptions, of Neolithic age or of more recent date; and the few that have been met with under circumstances indicating a possibility of Palæolithic age are too fragmentary to supply any satisfactory information as to the physical characters of the skeletons to which they have belonged. The fibula from the Victoria Cave at Settle, Yorkshire,[1] is not human. Prof. W. Boyd Dawkins[2] speaks of a human tooth from the cave at Plas Newydd as 'the only piece of the human frame of late Pleistocene age found in Great Britain.' The portion of a cranium discovered by Mr. Henry Prigg[3] in brick-earth at Westley, Suffolk, and figured by Mr. Worthington Smith,[4] was too small a fragment to give any idea of the form of the cranium of which it was a part. The humerus from Kent's Cavern, determined by the late W. Davies,

[1] Busk, Journ. Anthr. Inst. vol. iii. (1874) p. 392.
[2] 'Early Man in Britain,' pp. 192 & 225.
[3] Journ. Anthr. Inst. vol. xiv. (1885) p. 51.
[4] 'Man the Primæval Savage,' 8vo. London, 1894, p. 281.

and preserved in the British Museum (Natural History), is not certainly of Palæolithic age. The human remains which have the best claim to a Palæolithic origin have been found on the continent of Europe, and will be noticed farther on.

The Neolithic remains of this country have been studied by many competent workers. Dr. Thurnam,[1] in his elaborate papers on the 'Two Principal Forms of Ancient British and Gaulish Skulls,' refers all the primary interments of the Long Barrows to the Neolithic period. The skulls of this race are said to be long, oval, or dolichocephalic, having a breadth-index varying from ·65 to ·75; the sutures have a tendency to become obliterated. The supraciliary ridges are not strongly marked, and none of the features have an extreme development. The face is orthognathic, and the upper and lower jaws are comparatively small. The average height of these Long Barrow people, as deduced from their femora, is about 5 feet 5·4 inches. Many of the tibiæ are platycnemic.

The skeletons of the Round Barrows are referred by Dr. Thurnam to the Bronze period; they have short or brachycephalic skulls, with a breadth-index varying from ·74 to ·89; the supraciliary ridges are large, the jaws are big and prognathic; indeed all the features were strongly marked, and the average height was about 5 feet 8·4 inches. These deductions, made by Dr. Thurnam, seem to have been confirmed by subsequent writers.

To the Neolithic race Prof. Boyd Dawkins[2] refers the skeletons from Perthi Chwareu, which were described by Prof. Busk.[3] The breadth-index of these skulls is much higher than in the Long Barrow types, ranging from ·72 to ·78; but seeing that in all other respects both the skulls and limb-bones are said to agree with the Neolithic forms, as described by Dr. Thurnam, they are believed to belong to the same race.

The Galley Hill skull resembles the Long Barrow forms in being dolichocephalic, and its closest agreement is with the longest skulls of the race. The synostosis of the sutures is another point of resemblance, as is also the comparatively small size of the jaw and the projection of the chin, in which particulars our present specimen differs so markedly from the heavy jaw and receding chin of the Spy skeleton, to be presently noticed. The low stature of the entire skeleton (5 feet 1 inch), as deduced from the size of the femur, is also in agreement with the Long Barrow forms, but in this particular there is an equally close resemblance to the Spy race. The uniform size of the three molar teeth and the manner in which the crowns are worn to a level surface are peculiarities found in some at least of the Long Barrow men. On the other hand, the strong development of the supraciliary ridges, and probably the prognathic features, are very important characters, in which the Galley Hill skull differs markedly from the Neolithic race.

[1] Mem. Anthrop. Soc. vols. i., ii., iii. (1865–70).
[2] 'Cave Hunting,' London, 1874, p. 197.
[3] Journ. Ethn. Soc. 1871, reprinted in Boyd Dawkins's 'Cave Hunting,' p. 166.

The skulls from Perthi Chwareu above mentioned, as described by Prof. Busk, are less like the Galley Hill skull, inasmuch as their breadth-index (·72–·78) places them quite at the opposite extreme of the Neolithic race and brings them into nearer relation with the Round Barrow people, in which the breadth-index is from ·74–·89. Moreover, the Perthi Chwareu skulls do not show any tendency to synostosis of the sagittal suture.

The skull from the river-gravel at Tilbury, described by Sir Richard Owen,[1] whatever may be its age,[2] is unlike the Galley Hill cranium in both upper and side views; its exceedingly heavy brows approach those of the Neanderthal skull, but the forehead is fuller and more prominent.

Among the skulls referred to by Prof. Huxley in the 'Prehistoric Remains from Caithness,'[3] that from the bed of the river Nore at Borris, Ireland, presents many points of resemblance to the Galley Hill specimen:—'The supraciliary ridges are prominent, the forehead retreating, the probole large, and the superior curved line and occipital spine well marked'; besides this, the skull is much depressed, and when seen from behind has flattened and nearly vertical side-walls. The breadth-index is ·737 and the height-index ·68. Although the Borris skull is broader than that from Galley Hill, yet in other respects it makes a near approach to the latter.

2. Continental Fossil Human Remains.

Within the last ten years two remarkable human skeletons have been discovered in a cave at Spy, near Goyet, Namur, Belgium. They were found in such relation with remains of extinct mammals (*Elephas primigenius* and *Rhinoceros tichorhinus*) and flint-implements as to leave little room for doubt that they are of Palæolithic age. These human remains form the subject of an elaborate memoir by MM. Julien Fraipont and Max Lohest:[4] the skulls and other bones being described in minute detail and compared with the Neanderthal and other fossil human remains, which are believed by the authors to belong to the same Palæolithic race.

The two skulls from Spy are remarkable for the great development of the supraciliary ridges and for their receding foreheads; the latter character being especially marked in one of them, which in consequence agrees very closely with the famous Neanderthal calvaria. Seen from above, these two skulls further agree with that from the Neanderthal in being narrow behind the orbits; but they have broad and inflated parietals. Their breadth-indices are in one case ·70,

[1] 'Antiquity of Man as deduced from the Discovery of a Human Skeleton, etc.,' 8vo. London, 1884.

[2] Holmes, T. V., 'Notes on the Geological Position of the Human Skeleton lately found at the Tilbury Docks, Essex,' Trans. Essex Field-Club, vol. iv. (1885) p. 135.

[3] By Samuel Laing, with Notes on the Human Remains by Thomas H. Huxley, 8vo. London, 1866.

[4] 'La Race Humaine de Neanderthal, etc.,' Archiv. d. Biologie, vol. vii. (1887) p. 587.

and in the other about ·74 : that of the Neanderthal skull being about ·73. The occipital region in both specimens projects considerably, and in this particular they are not unlike the Long Barrow (Neolithic) skulls.

The Galley Hill skull resembles those from Spy in the possession of prominent supraciliary ridges and a projecting occipital bone; but its frontal region is fuller and more nearly of the normal type. When seen from above it is more parallel-sided and presents none of the inflation of the parietal region which is so marked in both the Spy and Neanderthal skulls; and it is this which results in the much lower breadth-index (·64 ?) of the Galley Hill cranium. Although this skull is somewhat narrower behind the orbits (100 millim.) than either of the Spy skulls (104–106 millim.), yet it has nothing like the same lateral projection of the orbits.

The lower jaw from Spy is remarkable for the depth of the horizontal ramus and for its vertical, or slightly receding, chin. The lower jaw from Galley Hill is comparatively small and has a projecting chin. In both specimens the teeth are worn to a nearly level surface, and the measurements of the three molar teeth are very nearly the same. The hindermost true molar of the Galley Hill jaw seems to have been as large as the first true molar; in the Spy specimen the corresponding last molar is one millimetre wider and thicker than either molar 1 or molar 2.

The femur of the Spy man, as described and figured, is robust and thick, with large articular extremities; the shaft is much curved forward, round in section, and has only a slightly prominent linea aspera. The neck forms a less obtuse angle with the shaft than is usually the case, and is twisted more forwards. The distal condyles extend abnormally forwards and backwards, and the inner one is so much longer than the outer as to indicate an unusual obliquity of the entire bone. The length of the Galley Hill femur is about the same as that of the Spy specimen, and its large proximal articular head is very similar, but in all other particulars it will be seen that the two bones are very different.

The Spy tibia is short and robust. The transverse section of the shaft is ovoid, and the angles are rounded; the hinder surface is particularly convex, and the interosseous ridge is placed far forwards. The transverse section of the Galley Hill tibia presents quite a different outline, for although the long and short diameters are very nearly the same in the two specimens, yet in this the interosseous ridge is farther back, the angles are sharp, and the hinder surface is flatter than in the Spy tibia.

The human skeletons from the cave of Cro-Magnon[1] belonged to a tall race, one skeleton indicating a man 5 feet 11 inches in height. The skull of this individual is dolichocephalic, with a breadth-index of ·73. The femur is strongly carinate, and the tibia excessively platycnemic. All these characters are unlike those presented by the Galley Hill skeleton.

[1] 'Reliquiæ Aquitanicæ,' p. 66; Boyd Dawkins, 'Cave Hunting,' p. 249.

The large skeletons from the Mentone Caves are said by M. E. Rivière [1] to possess the greater part of the characters of the Cro-Magnon race.

The Engis skull, originally described by Schmerling, was afterwards noticed and figured by Prof. Busk [2] and then by Sir C. Lyell [3] and Prof. Huxley.[4] It is described as dolichocephalic, with a breadth-index of ·70, and in this respect seems to approach the Galley Hill skull, but the two figures given by Prof. Busk do not at all resemble our specimen.

The dolichocephalic skulls of the primitive Basques, which were described by M. Broca,[5] were afterwards shown by Dr. Thurnam [6] to be very similar to those from the Long Barrows, and he believed them to belong to the same early race of men, the Neolithic. Prof. Boyd Dawkins holds the same opinion, the skulls from Perthi Chwareu being particularly like these ancient Basques. An examination of the skulls of this race preserved in the Museum of the Royal College of Surgeons shows that they are inflated in the parietal region, and in none of them does the breadth- or height-index fall so low as in the Galley Hill cranium.

3. Living Races of Men.

Among the races of Man now living there are several possessing dolichocephalic skulls, which it will be well to notice. The measurements and other particulars alluded to below are for the most part derived from Sir William Flower's [7] descriptions, but a number of the specimens in the Museum of the Royal College of Surgeons have also been compared, and for this privilege I am indebted to the kindness of the present curator, Prof. Charles Stewart.

The skulls of the Eskimo are long (169–201 millim.) and narrow (125–145 millim.), but none are so laterally flattened in the parietal region as the Galley Hill cranium, and there is an entire absence in them of the thickened supraciliary ridges; moreover, the characteristic flat face, caused by the forward projection of the cheek-bones and outer margins of the orbits, is unlike the Galley Hill skull, so far as one can judge from the broken portions of the orbit which are preserved. The measurements of the last-named specimen nearly all fall within the extreme dimensions of the Eskimo, in which race, however, the breadth-index varies from ·66 to ·78 and the height-index from ·69 to ·79.

The teeth in one Eskimo skull are as nearly as possible like those preserved in the Galley Hill specimen; but in another example the hindermost lower molar is smaller than the others. The Eskimo femur is very similar to that from Galley Hill, being flattened from

[1] Comptes Rendus Acad. Sci. Paris, vol. cxiv. (1892) p. 567.
[2] Nat. Hist. Rev. vol. i. (1861) p. 155.
[3] 'Antiquity of Man,' 1863, p. 79. [4] *Ibid.* p. 80.
[5] Bull. Soc. Anthrop. Paris, vol. iii. (1862) p. 579.
[6] Mem. Anthrop. Soc. vol. i. (1863) p. 120, & vol. iii. (1867) p. 41.
[7] Catal. Mus. Roy. Coll. Surg. part i. 1879.

before backwards and possessing a large articular head; it differs, however, in having a stronger linea aspera and in the larger size of the lesser trochanter. The forms of the tibiæ, as shown by their transverse sections, are also much alike in the two skeletons: the measurements of their longer and shorter diameters being almost identical. The height of the skeleton, No. 834, in the Royal College of Surgeons is, as nearly as possible, the same as that calculated for the Galley Hill man; the femora only differing by at most 3 or 4 millimetres.

Negro skulls are long and narrow (breadth-index ·64–·81), but their height is proportionately greater, the index, seemingly, never falling so low as it appears to be in the Galley Hill specimen. There is little or no development of brow-ridges; the forehead is fairly prominent, and the interorbital width is greater than it seems to have been in the Galley Hill skull. There is some variation in the size and proportions of the negro's molar teeth; in some, the last lower molar is as large as the two which precede it, but in other cases it is decidedly smaller. The tibiæ are more slender and more platycnemic than in the Galley Hill skeleton.

None of the Australian skulls in the Royal College of Surgeons have so low a breadth-index (·68–·77) as the Galley Hill skull, but the height-index may fall lower (·63–·82). In the possession of thickened brow-ridges and receding foreheads, there is a resemblance to our specimen. The teeth vary much in size and proportions; all the molars are sometimes very large, and the hindermost may be larger than those in front of it, or it may be markedly smaller. The tibiæ are not platycnemic, but very similar to those of the Eskimo and Galley Hill skeletons.

The Fijians exhibit as extreme a condition of dolichocephalism as any known race, their cephalic index falling in some cases as low as ·619, while it is not known to rise higher than ·714; the height-index, however, is proportionately greater, ranging from ·72 to ·78. The lateral flattening of the parietal region in the Fijian crania makes a nearer approach to that of the Galley Hill man than any other form, excepting perhaps the Melanesian to be presently noticed. The Fijians have strongly developed supraciliary ridges, as large possibly as in the Galley Hill skull; but the forehead is fuller and more prominent, while the probole is less projecting. The lower molars of the specimen measured (1127, Roy. Coll. Surg.) are more nearly equal in size than in any other instance I have seen (see Table II., p. 509).

The remarkable Melanesian skull described by Mr. Oldfield Thomas[1] is much narrower than that from Galley Hill, its breadth-index being only ·619, and seen from above the outlines of the two skulls are very similar. In both the supraciliary ridges are very strongly developed, but the forehead is somewhat fuller in the Melanesian than in the Galley Hill skull; also in the latter the probole is more prominent and the occiput more flattened below. In a side-view,

[1] Journ. Anthrop. Inst. vol. xiv. (1885) pls. xiv. & xv.

the Galley Hill skull is apparently more depressed than is this Melanesian, but the height-index of the latter (·649) is less than that calculated for the former (·674 ?). This seeming discrepancy may in part be due to the natural flattening below of the occiput in the Galley Hill skull, and in part to a too liberal allowance being made in the endeavour to calculate the probable height without a definite basal point.

4. General Remarks on the possible Affinities of the Galley Hill Remains.

Briefly stated, the more important characters of the Galley Hill skull are its length and narrowness, for it is extremely dolichocephalic, unusually parallel-sided, and much depressed. The small extent, both in height and width, shows that there has been little or no *post-mortem* compression, and only such changes as may be due to shrinkage in drying since it was exhumed. The supraciliary ridges are large, the forehead moderately receding. The temporal ridge extends far up towards the top of the skull. The probole projects far backwards. The underpart of the occiput is much flattened. The last lower molar is as large as either of the two in front of it. All the main sutures are closed and nearly obliterated.

The closure of the sutures at once suggests the possibility of this skull being scaphocephalic as a consequence of this closure ; there is nothing, however, but the shape to support this idea. The individual must have been middle-aged, for not only is the last molar in place, but it is well worn ; and, for all we know, there may have been no premature synostosis, but only such as appears to be commonly met with among the Long Barrow race. In none of the skulls mentioned in this paper is the lateral flattening so marked as in the one here described, and among the ancient skulls hitherto known it is only in the Long Barrow race that the breadth-index falls so low as it does in the Galley Hill skull. So few examples of the Spy race are known that it may well be, when more are discovered, that lower indices will be met with ; but this is hardly likely to be the case with those races of which a good number have been measured. In other particulars the Long Barrow skulls are less like our specimen, for the height-index is never so low, the forehead is better developed, and there is no marked thickening of the supraciliary ridges.

The river-bed skull from Borris, Ireland, noticed by Prof. Huxley, is the one which, in a side-view, comes nearest to that from Galley Hill ; its supraciliary ridges are large, the entire skull is much depressed, the probole is large, and there is a flattening of the underpart of the occiput ; but, although this skull is dolichocephalic, its breadth-index (73·7) is much higher than in the present skull and agrees very nearly with that from the Neanderthal.

The age of the Borris skull is uncertain, but is regarded by Prof. Huxley as representing an extreme form of the most ancient race whose remains have been met with in Ireland, and he identifies

this race with the Long Barrow type of England and the 'cumbecephalic' inhabitants of Scotland. The Professor also sees a similarity between these, the Scandinavian and the Eskimo types; moreover he agrees with Dr. Thurnam in recognizing a relationship with the ancient Basques. Further than this, he traces in the Australian of the present day the same type, and thinks that the famous Neanderthal cranium is more nearly approached by the Australian skull than by any other.

Attention has already been directed to the similarities between the Galley Hill skull and those of the Eskimo, as well as to its resemblance to those of the several dolichocephalic races of the south. In each of these races, however, there are important differences which prevent our specimen from being referred to any one of them.

If I am well-advised in supposing that the Galley Hill skull may be nearly related to the Borris skull, and this represents, as Prof. Huxley thinks, the most ancient race known in Ireland and an extreme form of the Long Barrow type of England, then the Galley Hill skull would be a still more extreme form of this same race, which is generally regarded as Neolithic. But may it not be that the Borris and Galley Hill skulls really represent a still earlier type of man, differing from the Neolithic race in the stronger development of the supraciliary ridges, in the more receding forehead, and in the flattening of the underpart of the occiput?

It may be objected that we already know the earlier or Palæolithic race, as represented by the Spy and Neanderthal remains; but, although this may be true for the European continent, it may not be so for Great Britain or Ireland. Hitherto we have not known any of the physical characteristics of the race which made the Palæolithic implements found in Britain. It has been supposed by some writers that there is no real break between the Palæolithic and Neolithic races, but that a gradual change in the type of implements may be traced, indicating a gradual development of the race that made them. If this be the case, then it might be that the Neolithic people descended from a Palæolithic race, represented by the Galley Hill and Borris skulls; having in the meantime developed higher crania, a fuller frontal, and rounder occipitals, at the same time losing the strong supraciliary ridges.

Prof. Boyd Dawkins, however, thinks that the Palæolithic is a distinct race from the Neolithic, as their different modes of life and artistic talents seem to indicate, and further believes that the Eskimos are descended from the former race. If this be correct, and if the Galley Hill man represent the Palæolithic race, then the Eskimos have lost the strong supraciliary ridges and developed their characteristically broad and anteriorly directed malar bones.

It must be allowed that the characters presented by the Galley Hill remains are not such as will permit of any very definite conclusions being drawn as to the precise race to which they may have belonged.

IV. Remarks on the Age of the Gravels in which the Human Remains were found.

It was in the year 1888, and soon after the remains were found, that Mr. Elliott brought the skull for me to see; but as it was his intention to describe the remains himself, they were not left with me, and it was not until last July (1894) that I again saw the specimen. As it was evident that the interest of this discovery would depend upon our knowing the exact circumstances in which the remains were found, I requested Mr. Elliott to put in writing all the facts, so far as he had noted them at the time or could remember, as to the finding of the skeleton, also as to the condition of the bones and of the gravel in which they were found, and the following is his reply:—

'According to my promise, I write to let you know the particulars of my find of human remains in undisturbed gravel, capping the Chalk, at the top of Galley Hill, in Kent, at the end of September, 1888.

'It was my custom to visit the pits at Milton Street, Swanscombe, Galley Hill, and neighbouring excavations every fortnight regularly (in search of flint-implements) for more than two years before the discovery of the human remains—so that I was well acquainted with the pit beforehand.

'In 1888 the chalk-pit itself was considerably smaller than now, and was constantly worked for chalk, used in the Cement Works, the gravels on the top being removed and 'screened' on the spot. Thus the removal of the gravel had to keep pace with the excavations of the chalk beneath, so that several tons were removed daily and carted away.

'It was on one of my fortnightly visits that I was informed by a man, named Jack Allsop (who had for a long time looked out and saved for me any implements or stones of similar shape, obtained while screening the ballast) that he had found a skull under the gravel. This I could hardly credit at first; but on my asking him to show it to me, he produced it in several pieces from the base of a pillar of laminated clay and sand, where he had hidden it. I asked where the rest of the bones were; he pointed to the section opposite this pillar, and a few feet from it, and told me that he had left the other bones undisturbed, for me to see; and there, sure enough, about 2 feet from the top of the Chalk, and 8 feet from the top of the gravel, portions of bone were projecting from a matrix of clayey loam and sand. He also told me that several of the men employed at the works, the master of the neighbouring school, and others, had seen the skull.

'The section of gravel was 10 or 11 feet thick, and extended for a considerable distance along the south and east end of the pit; several pot-holes or pipes running from it, deep into the Chalk.

'I carefully examined the section on either side of the remains, for some distance, drawing the attention of my son Richard, who was with me, and of Jack Allsop, to it. It presented an unbroken face of gravel, stratified horizontally in bands of sand, small shingle, gravel, and lower down beds of clay and clayey loam, with occasional stones in it—and it was in and below this that the remains were found. We carefully looked for any signs of the section being disturbed, but failed: the stratification being unbroken, and much the same as the section in the angle of the pit remaining to this day, but it was then clear and not covered by rubbish as it now is in places, all the 'callow' and loam at the top being at that time removed to allow of the gravel being got at.

'I went on my knees, and, with the point of my geological hammer and a knife, tried to work round each piece of bone, but soon gave up the attempt, as the bones were so friable and fragile that many went to pieces as soon as touched—so that I decided to work about a foot, each way, from the bones.

'Jack Allsop and I went to work, and we were fortunate enough to obtain the fragments which are now in your keeping. So friable were they that we had to place them on soft, newly screened sand to harden in the atmosphere, where I allowed them to remain between 4 and 5 hours, by which time they became a little hardened, and I carefully wrapped them in soft paper and brought them home.

'These bones had been left *in situ* by Jack Allsop, because of their being too soft

for him to get out, and also in order that I should see them exactly as he found them.

'Within a few days of my obtaining them, you will, I think, remember that I brought the skull to you in pieces, and you kindly offered to piece the remains together for me; but I preferred taking them away, as I then intended to work the subject up, and describe and publish my find. This I have been unable to do, not having the necessary leisure from business, and I regret not having placed them in your hands before.

'The remains have been in my museum ever since, and no one has interfered with them, except myself and a few friends in my presence. So you have them exactly as they were found, except that I have dipped them in a solution to preserve them.

'In May last my friend Mr. Frank Corner, of Poplar, saw these remains and urged me to place them in someone's hands, so that a description of them might be published. In June Mr. Worthington Smith examined the remains, and seemed much impressed with their peculiarities of structure.'

(Signed) Robert Elliott,
Camberwell, July 1894.

Mr. Matthew H. Heys, of Greenhithe, who in 1888 was master of the school which stands close to the pit at Galley Hill, appears to have been the first person who saw the skull when it was uncovered by the workmen in excavating the gravel; and in answer to my enquiries, this gentleman, who has paid some attention to geology, in a letter gives me information which not only confirms what Mr. Elliott has already stated, but adds the important fact that he saw the skull *in situ* before it was removed from its ancient resting-place. Mr. Heys's observations as to the undisturbed condition of the gravel are likewise strong evidence in favour of these remains being of the same age as the gravels in which they were found. He writes as follows:—

'In reply to your enquiries concerning the skull found in this immediate neighbourhood, I have to say that my attention was called to the spot by the workman who unearthed it, and before it was removed from its long resting-place. For the moment, I was tempted to appropriate it there and then, but when I examined it more carefully I was struck by the undisturbed condition of the gravel in which it was embedded; it seemed as though gravel and skull were deposited at the same time.

'I had only a few spare moments at the time, for I was called back to my school duties.

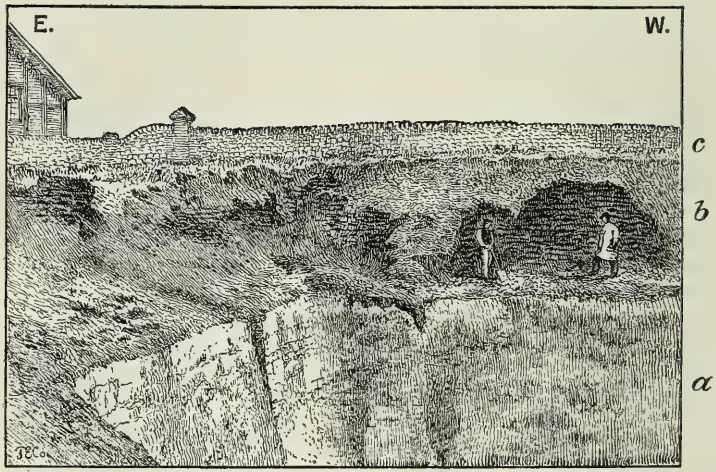
'My intention was to obtain some indisputable record of its position in the gravel by photographing it *in situ*, or by the testimony of one or two intelligent people. What was my chagrin, when I visited the spot again, to find that it had been removed! I was so disappointed that I tried to forget and banish it from my mind. Had I realized the value of the find as I now do, I should have mounted guard over it and not allowed its removal till such record as that above mentioned had been obtained.'

(Signed) Matthew H. Heys,
Greenhithe, February, 1895.

Galley Hill, as marked on the Ordnance map, is not quite $\frac{3}{4}$ mile north-west of Northfleet station. North of the high road is a large chalk-pit in which are the cement-works now using the chalk. The spot where the human remains were found is at the south-eastern corner of the pit, near the main road. The Chalk here rises to a height of nearly 90 feet above the Thames, and is capped by gravel, 9 or 10 feet thick, but thinning towards the east and west. Southwards the gravel extends to Swanscombe and Milton Street, from both of which places, as well as at Galley Hill, Mr. Elliott has obtained many Palæolithic implements. The Chalk and overlying

gravel in 1888 had been worked southwards nearly to the high road, so that less alteration has been made since than might have been expected: in fact, the chalk which supported the gravel still remains; but the gravel itself, which contained the bones, has been removed, and the present face of the pit is about 10 feet from the exact spot. This change, although slight, is quite sufficient to prevent that verification of the undisturbed condition of the gravel overlying the skeleton which, under the circumstances, is so desirable—more especially as no experienced geologist saw the spot in 1888, when the discovery was first made.

Fig. 1.—*Chalk and Gravel Pit, Galley Hill, Kent. (S.E. corner of pit, looking S.)*



a=Chalk. *b*=Gravel. *c*=wall, behind which is the high road. The figure on the right is represented as standing on the spot where the human remains were found.

(From photographs by Mr. Clement Reid and Mr. J. W. Reed.)

My lamented colleague, Mr. Topley, after examining the section with us in July 1894, was of opinion that the gravel then standing above the Chalk was in an undisturbed condition, and, judging from its relation to the gravels of the surrounding area, considered it to be part of the high-level terrace-gravel of the Thames Valley. Mr. Clement Reid visited the pit with us in April 1895, when a clean face was made to the gravel, as close as possible to the spot where the bones were found; and the stratification of the beds, in the section thus exposed, convinced him that the gravel was undisturbed.

Mr. Whitaker,[1] in his memoir, alludes to the gravel at Northfleet

[1] Mem. Geol. Surv. 'Geology of London,' 1889, pp. 440, 441.

and Swanscombe as high terrace-gravel; and that at Galley Hill is continuous with the gravel at the latter locality.

Prof. Prestwich mentions the gravel at Milton Street, which joins that at Swanscombe, as 'the high-level river-drift of the Thames Valley'; and says, 'It contains flint-implements of a distinct and more advanced type than those of Ash and Westyoke [plateau gravels], while at a lower level still are brick-earths and gravel with extinct mammalian remains and implements of a yet later period.'[1]

The flint-implements found in this gravel at Galley Hill (p. 505) are similar to those from the pits at Swanscombe and Milton Street, and are of acknowledged Palæolithic type; most of them are pointed and well worked, some being worked over the whole surface, including the rounded end, while others have part of the base unworked and still showing the natural surface of the flint. Mr. Elliott has obtained several types of implements from this pit; namely, tongue- or spear-shaped forms, ovoid implements, hand hatchets, chipping tools, drills or borers, and flakes of various kinds. Many, if not most, of these implements have the edges sharp and almost unworn, showing that they have undergone but little rolling. There are also many rude flakes and roughly-chipped flints in this gravel, the human origin of which might be doubted if they were found alone; and occasionally deeply-stained primitive forms are met with, similar to those found by Mr. B. Harrison on the high plateau near Ightham. Several roughly-chipped flints and two very perfect implements were found by us on our recent visits to the pit. (See fig. 2, p. 523.)

So far as I have been able to ascertain, no mammalian remains have hitherto been obtained at Galley Hill itself; but Mr. Frank Corner possesses a *Hippopotamus*-tusk found at Milton Street by Mr. W. H. Smith, of Canning Town, who says that the tooth was obtained in 1889 at about 6 feet from the surface, in the brick-earth which overlaps the coarser gravel. Mr. Elliott has a deer's antler from the same place and some unrolled footbones of *Felis leo* from brick-earth, occupying a similar position at a high level, in a pit near Swanscombe.

Mr. F. C. J. Spurrell, of Belvedere, has found *Elephas primigenius*, *Rhinoceros* sp., *Bos*, *Equus*, and *Cervus* in the small patch of gravel near Northfleet Station; also these same species in the similar terrace-gravel at Dartford Brent, west of the City Asylum, besides other remains at intermediate localities. Mr. Spurrell's specimens were all found at the base of the gravel near the Chalk, and were in a much decayed condition. Speaking of the last-named locality, Mr. Spurrell says (*in lit.*):—'The lower layers still contained a large quantity of fine chalk, besides which the sand there had a large quantity of Woolwich-bed shells washed out clean; together these helped to protect the more recent shells from complete dissolution, and to preserve the only freshwater shells that I have seen in this

[1] Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 129.

gravel—namely, *Cyrena fluminalis*, *Bithynia tentaculata*, *Valvata piscinalis*, and *Pisidium fontinale*.'

No one is better acquainted with the North Kent Pleistocene deposits than Mr. Spurrell, and he agrees with other writers in regarding these gravels, which extend from Dartford Heath to Gravesend, at a height of about 100 feet O.D., as parts of one original stretch of deposits, and the gravel now standing in the Galley Hill pit he believes to be an undisturbed portion of the same deposit.

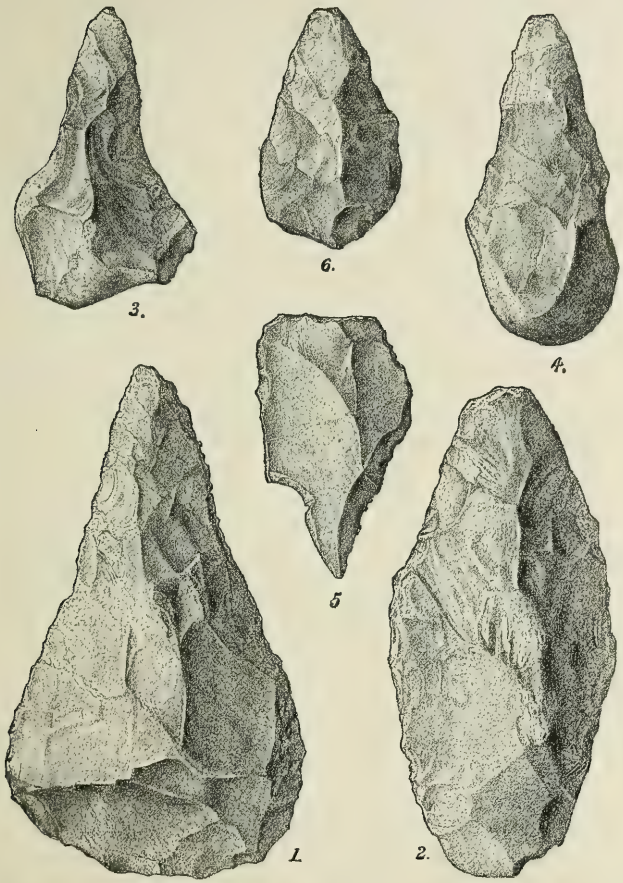
Mr. Spurrell tells me that human bones have previously been met with, ostensibly from these gravels, but no record has been kept of the conditions under which they occurred. He doubts whether the human bones described in this paper are really of the same age as the gravels.

The fact that the surfaces of the Galley Hill bones have been eaten away by rootlets has led to the inference that the gravel in which they were found had been disturbed, for it has been thought that rootlets would not penetrate this terrace-gravel to so great a depth as 8 feet when it was in an undisturbed condition. However, on the occasion of one of our later visits to Galley Hill Mr. Elliott and Mr. Frank Corner traced living roots descending from the surface-soil through about 8 feet of undisturbed gravel down to the same level as that where the human bones were found, and within a few feet of the same spot. Also at Wanstead, in Essex, we have obtained roots from a depth of 7 feet below very similar gravel, containing Palæolithic implements, the undisturbed condition of which could not be doubted.

No one would, I think, question the Palæolithic age of this gravel at Galley Hill and in the neighbourhood, or the genuineness of the implements found in it, but for the finding of the human bones; this discovery, however, at once causes all manner of doubts to arise and renders it necessary to test every possibility of error. It may be thought that this northern edge of the sheet of gravel has been re-deposited by washing downhill towards the Thames; but this idea is not supported by an examination of the gravel now in place. Thus, although there is a thinning of the beds to the east and west (and doubtless also to the north, before the excavation of the pit), the bedding of the gravel and sand still to be seen in the section led Mr. Topley, Mr. Clement Reid, and Mr. Spurrell to the conclusion that this part of the gravel is undisturbed. It may be thought that this skeleton was let down from the surface in a more recently formed 'pot-hole,' but although such excavations are numerous in the adjacent Chalk, yet immediately below the spot where the bones were found (and the chalk still remains) there is no 'pot-hole.'

The possibility of these human bones being the remnants of a comparatively modern burial will occur to every one, but the peculiar characters presented by these remains point to their being of considerable antiquity, and the depth at which they were found—namely, below about 8 feet of gravel—is greater than in the case of most prehistoric interments. Moreover, there is no evidence

Fig. 2.—*Palæolithic Flint-implements from the Terrace-gravel at Galley Hill, Kent.*



Nos. 1 and 2 are chipped all round; 3 and 4 have a large portion of the original rounded surface of the flint left at the base; 5 is a flake worked on one side only; 6 is worked all round, except a small surface at the base. Specimens 1 to 5 were obtained by Mr. R. Elliott. No. 6 was found by the present writer in the gravel, during a recent visit.

(All the figures are half natural size.)

whatever of this being an interment; and the two observers who saw the bones *in situ* are perfectly satisfied that the remains were deposited with the gravel and not as a subsequent burial.

The rarity of bones in these high-level gravels suggests the possibility of their having been removed by the continued percolation of water during the long period which has elapsed since they were deposited. It still further suggests that, if any human bones had been deposited with the gravel in Palæolithic times, they would long since have disappeared. However, bones of certain extinct mammals, *Elephas*, *Rhinoceros*, *Hippopotamus*, and *Felis leo*, have occasionally been found, although generally in a much decayed condition, and the circumstances, sufficiently favourable for their preservation, may have obtained in other places also. Indeed it is clear from Mr. Elliott's letter, and from my own observation in the pit, that patches of more clayey deposit do here and there occur, one such having been noticed very near where the skeleton was found.

The statements made by Mr. Elliott and Mr. Heys as to the undisturbed condition of the gravel above the skeleton, when it was first found, and which they saw *in situ*, are the most important pieces of evidence, as to the age of the remains, which it is now possible to obtain; and it is much to be regretted that the observations of these gentlemen were not at the time confirmed by some geologist experienced in the study of Pleistocene deposits.

Impressed with the desirability of this discovery being permanently recorded, and feeling that the interest of it will depend upon the establishment of the geological age of the remains, I have ventured to bring this paper before the Geological Society, where the points at issue will be best understood and most freely criticized; but, if Mr. Elliott's and Mr. Heys's observations are correct, there can be little doubt as to the Palæolithic age of these human remains from Galley Hill.

EXPLANATION OF PLATE XVI.

Human Remains discovered by Mr. Robert Elliott, in the High Terrace-gravel at Galley Hill, near Northfleet, Kent.

Fig. 1. Skull, side view (*norma lateralis*), with right half of mandible placed in position. Half natural size. The dotted lines show the probable position of the missing facial bones.

2. Molar and premolar teeth, grinding surfaces. Natural size.
3. Skull from above (*norma verticalis*). A series of dots indicate as nearly as possible the middle line, and show the torsion undergone in drying. Half natural size.
4. Skull from front (*norma frontalis*). Half natural size.
5. Skull from behind (*norma occipitalis*). Half natural size.
6. Left femur, front view, with outline of transverse section. One-fourth natural size.
7. Left femur, inner aspect. This bone is really much more denuded than it appears to be in these figures.
8. Right tibia, much broken; seen from front, with outline of transverse section. One-fourth natural size.

Discussion.

Mr. Elliott said that the whole of the particulars appertaining to his discovery were embodied in his letter to the Author, and there was therefore very little to add. When he made the discovery he closely examined that portion of the pit in which part of the remains were still lying *in situ*, and felt certain that the gravel above them was undisturbed. There was one matter to which he wished to refer, and that was the reason why he had left the remains so long before bringing them to the notice of the Society. He had a desire to describe them himself; but, finding this impossible, he had decided to place the remains in the hands of Mr. E. T. Newton.

Mr. Heys said that the letter read by the Author contained the facts, so far as he had been able to ascertain them. He had seen the skull *in situ*, and was struck with the depth below the surface at which it lay, and by the natural stratification of the gravel in close contact with it. He had left the skull in place, in order that he might obtain corroborative evidence, or have it photographed; but to his great annoyance it had been removed by the workman when he again visited the spot.

Sir John Evans expressed his high appreciation of the great care and wealth of detail that Mr. Newton's paper exhibited. It seemed to him that the communication might be divided into two absolutely distinct sections—the one anthropological, the other geological. It was on the latter branch of the subject only that he proposed to say a few words. There could be, he thought, no doubt of the deposits at and near Swanscombe being true Pleistocene high-level gravels of the valley of the Thames; and the abundance of Palæolithic implements that occurred in them seemed to place their age beyond all doubt. With regard to the human remains, the real question at issue was whether they were deposited where found with the other constituent parts of the gravel, or not. It was unfortunate that so long a period had elapsed between the discovery of the bones and the attention of geologists being called to it. The evidence, however, of the undisturbed character of the beds seemed fairly strong, though, so far as he had understood the paper, one witness described the bones as having been found in gravel and the other in loam. Perhaps, however, both might mean the same deposit. The fact that the remains were found, not at the base of the gravels, like other bones from the same locality, but some few feet above the Chalk, was noteworthy; but what weighed most with him, and led him to doubt whether the bones were of the same age as the gravels, was the fact that nearly the whole skeleton, including the lower jaw and clavicle, had been preserved. Although occasionally in brick-earth the bones of a limb might have been found together, it might be regarded as almost if not quite universally the case that in gravels isolated bones only were found. The occurrence of a nearly perfect skeleton was suggestive of an interment; and the accumulation of surface-soil above the gravel might give the grave in which the body

was deposited an appearance of having been of greater depth than it actually was. On the whole, he ventured to maintain an attitude of doubt, and would await further evidence before absolutely accepting these human remains, however ancient, as being of necessity contemporaneous with the beds in which they were found.

Prof. Boyd Dawkins congratulated the Author on the manner in which he had placed this discovery before the Society. He accepted the views of Sir John Evans with regard to the absence of distinct proof that the skeleton really belonged to the same age as the Palæolithic gravels. In his opinion the skeleton was probably the result of interment in the Palæolithic gravels at a later time. He regretted that the skull had not been compared with Scandinavian Long Barrow skulls. The race to which the skeleton belongs was an open question, and the geological age was also not clearly proved. They may safely be placed to a suspense account.

Dr. Garson said that in his opinion the special characters shown by this Galley Hill skeleton were:—the short stature, the very dolichocephalic skull, the prominent glabella and supraciliary ridges and the well-marked ridges of the skull generally, the absence of prominence of chin, and the large size of the last lower molar tooth, which was as large as, if not larger than, the first molar. The large size of the head of the femur was also peculiar. He did not think that the specimen showed any signs of pathological conditions being present. Nor did he consider that this was a modern skeleton, neither could he refer it to the Bronze or Round Barrow races. Although the dolichocephalic skull and short stature agreed with the Neolithic race, yet the prominent brow-ridges were quite unlike. Moreover, the last lower molar in the Neolithic skull was smaller than those in front of it. Accepting the Spy, Neanderthal, and Naulette specimens as representatives of the Palæolithic race, he was inclined to think that the Galley Hill skeleton was most nearly related to that race. The long form of the skull from Galley Hill, when seen from above, did not agree with the Continental forms, and it would be necessary to compare many skulls of the race in order to determine whether this was more than an individual variation.

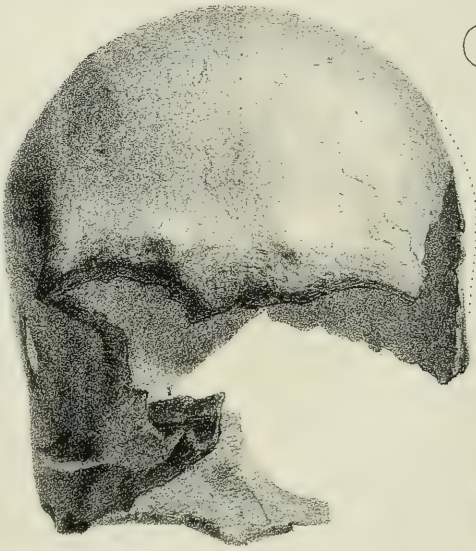
Mr. W. J. Lewis Abbott pointed out that bones of the same animal had often been found in juxtaposition. On one occasion he had found at West Thurrock the greater part of a mammoth in gravel, overlain by an intercalated sheet of clay. He had worked the Galley Hill section, and had obtained from it numerous implements and flakes, some of which were so sharp as to suggest their having been made on the actual spot. He had noticed here and there thin lenticular patches of very tough clay. It was in all probability under a sheet of such impervious material as this that the human remains had been preserved.

Mr. J. Allen Brown congratulated the Society on the production before it of the best authenticated record of the occurrence of human remains in the higher river-drift that had yet been brought forward in England. As to placing this discovery to a suspense account, although great caution was necessary, he must add that they could

3 x 1/2

2 x 1/1

7 x 1/4



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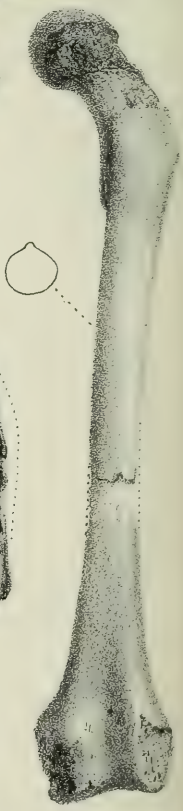

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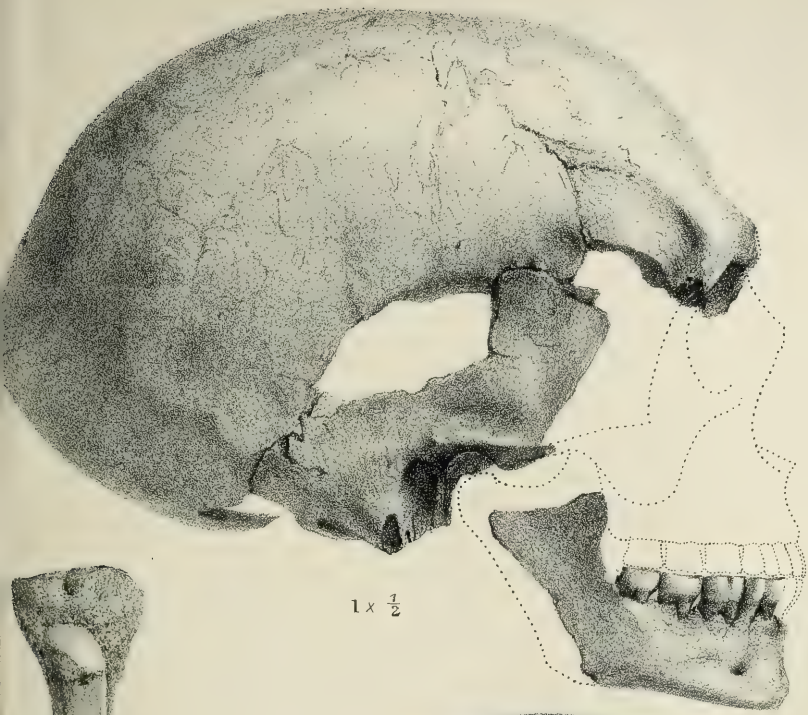

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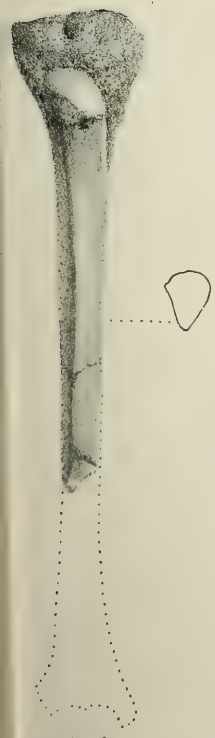

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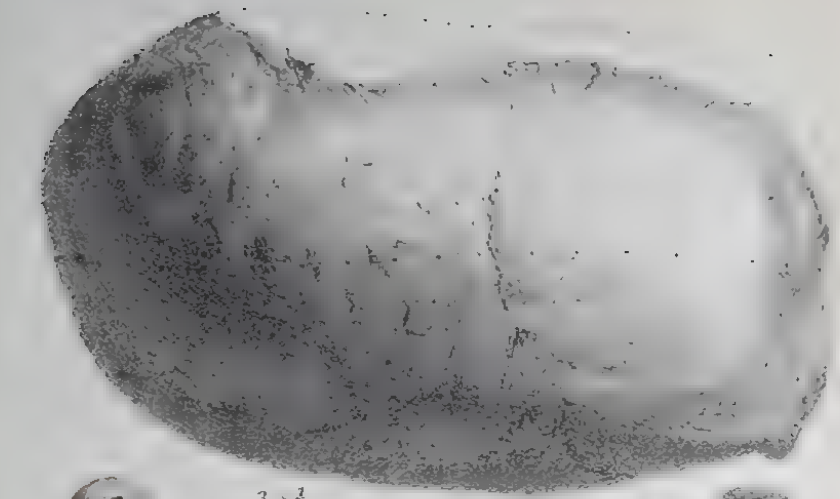

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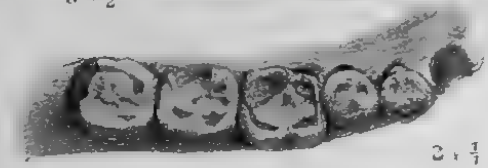

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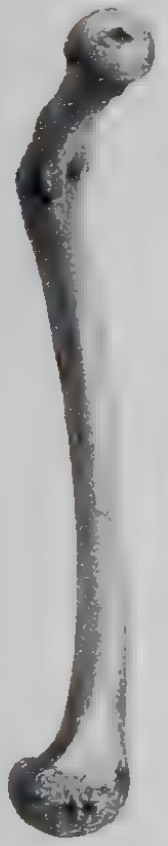

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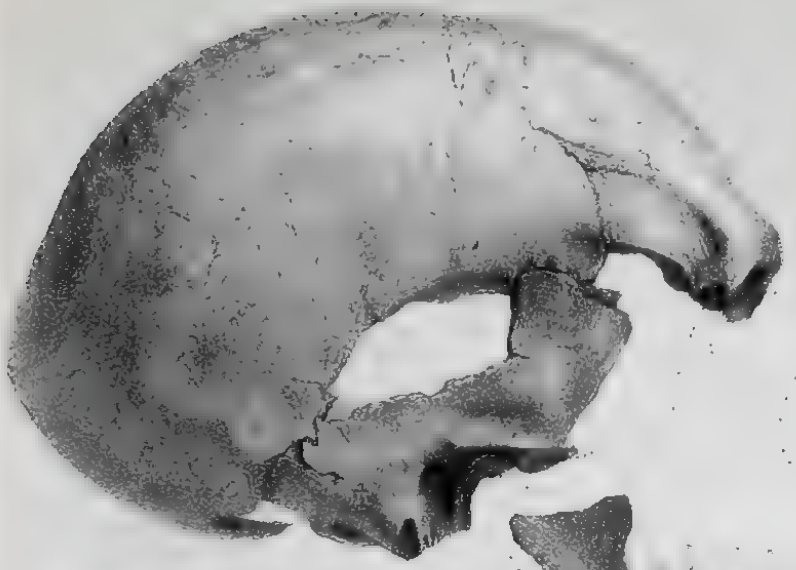

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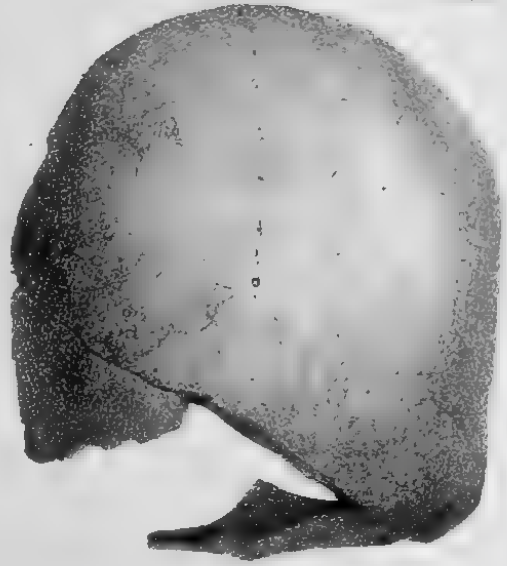

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HUMAN REMAINS FROM TERRACE-GRAVEL, GALLEY HILL, KENT

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hardly expect to obtain a much better attested instance than in the one before the meeting; the silty clay-bed in which the fossils appear to have been found was just the kind of deposit in which bones were commonly met with in river-drift, and they probably owed their preservation to the deposit being less permeable than the gravel above them. With regard to the skull, the river-drift period was of such long duration that there was time enough for the migration of many races of men into this country, and there was every probability that different types of Palæolithic people lived at the same time in N.W. Europe. As a believer in the continuity of man's existence there from the Palæolithic to the Neolithic period, it was not surprising to him to find a skull in the drift which showed affinities both with some of the Palæolithic skulls and those of the early Neolithic period as in the specimen before them.

Prof. Sollas regretted that the evidence for the absence of interment was not more perfect. Mr. Heys had only seen the skull in position for a few minutes, but Mr. Elliott's evidence was less open to question. The anatomical characters, as described by Mr. Newton, seemed, however, to show that the skull belonged to the same type as the Neanderthal and Spy skulls, the latter of which was clearly Palæolithic; it was hence highly probable that the Galley Hill specimen, which occurred along with Palæolithic implements, was in a natural position and had not been interred.

The Author, in reply, thanked the speakers for their kind criticisms. The object of the discussion was to elicit truth and eliminate error. In the present instance, he believed that the chain of evidence of the Palæolithic age of the remains was complete; although some of the links were not so strongly wrought as could be wished.

39. *On the* Occurrence *of* Spirorbis-limestone *and* thin Coals *in the* so-called Permian Rocks *of* Wyre Forest; *with* Considerations *as to the* Systematic Position *of the* 'Permians' *of* Salopian Type. By T. Crosbee Cantrill, Esq., B.Sc. Lond. (Communicated by Walcot Gibson, Esq., F.G.S. Read June 19th, 1895.)

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I. Introduction.

The occurrence of a band of *Spirorbis*-limestone associated with a thin coal-seam in red rocks which have hitherto been regarded as Permian in the district of Wyre Forest and Enville cannot but affect our ideas as to the systematic relationships of these beds, and may also have some influence on the mining prospects of that virgin strip of red ground which, narrowing from 14 miles broad at Madeley and Wolverhampton to 6 between Compton and Stourbridge, separates the coalfields of Coalbrookdale and Wyre Forest on the west from that of South Staffordshire on the east.

This red ground consists of the 'Permian' rocks and all the members of the Trias. Crossing from west to east we pass successively from Coal Measures at Madeley on to 'Permian' [e^1 of the Geological Survey map], Lower, Middle, and Upper Bunter, Keuper Sandstone, and Marl, till we reach Codsall, when we again pass over the same series in inverse order—omitting the Lower Bunter—till we reach the Coal District of Wolverhampton.

At the base of the Trias in this district there seems to be a marked unconformity, for at Bridgenorth the base of the Lower Bunter [f^1] is represented on the Geological Survey map, 61 S.E., as approaching the base of the Permian, whereas between Enville and Claverley it rests on the highest beds of the Permian; and

Prof. Hull[1] estimates the overlap as equivalent to about 1000 feet of strata. The horizontal extent of the overlap appears to be about 5 miles.

Between the base of the Lower Bunter of Enville and Claverley, and the Coal Measures of the Wyre Forest Coalfield, we have a thick series of red sandstones, marls, and cornstones, with several bands of calcareous conglomerate and the remarkable trappoid breccia. The whole has hitherto been regarded as Lower Permian, the representative of the Rothliegende of Germany.[2] It has been called by the Survey 'Lower Red Sandstone or Permian' [e^1] on the maps.[3]

The base was drawn at the plane which separates the red rocks above from the yellow, brown, and olive-coloured coal-bearing sandstones and shales of the ordinary Coal Measures below. Not that there are no occasional red beds among the ordinary Coal Measures, but that there were then not known to be present in these 'Permian' rocks any of the seams of coal, the *Spirorbis*-limestones, or the yellowish and grey sandstones, and blue, grey, or dark shales so characteristic of the Coal Measures.[4]

Besides this there are beds of calcareous conglomerate and trappoid breccia in these 'Permian' rocks, such as are not known to occur in the underlying Coal Measures; and, in addition, there is probably a certain small amount of local unconformity between the two series.

And, so far as the Wyre Forest and Enville district is concerned, the matter has remained till the present much as it was left by the Survey.

II. The South Staffordshire 'Permian.'

Before examining the fresh evidence which has lately come to hand in the Wyre Forest district, and which tends to show that these red rocks are much more closely allied to the Coal Measures than has hitherto been suspected, we will examine the progress of opinion as to the relations of similar beds in South Staffordshire.

In this latter district, Jukes, in his classic memoir, regarded as 'Permian' the whole of the red beds between the boundary-faults of the coalfield and the overlying Bunter. The same beds, to the south, overlie the olive-brown and yellow Hales Owen Sandstones of the Coal Measures, and rising to form the Wychbury, Clent, and Romsley Hills, are themselves overlain on the southern flanks of these hills by the Pebble Beds of the Middle Bunter.[5]

[1] 'Triassic and Permian Rocks of the Midland Counties of England,' Mem. Geol. Surv. 1869, p. 32.
[2] *Ibid.* p. 10.
[3] Sheets 61 N.E. & S.E., 62 N.W. & S.W., 55 N.E., & 54 N.W., etc.
[4] Hull, *op. cit.* p. 12.
[5] See Geological Survey map, Sheets 62 S.W. & 54 N.W.

(1) The Clent District.

The following seems to be the succession in the Clent District:—

'Permian' Rocks of the Clent District.

Lower Red Sandstone. [Rothliegende.]
- 2. Breccia and Conglomerate Group.
  - *g.* Trappoid breccia.
  - *f.* Sandstones and marls.
  - *e.* Calcareous conglomerate.
  - *d.* Sandstones and marls.
  - *c.* Calcareous conglomerate.
  - *b.* Sandstones and marls.
  - *a.* Calcareous conglomerate.
- 1. Lower Sandstones and Marls.

The breccia has been estimated to be about 450 feet thick, and the remaining beds, below it, not less than 500 feet.[1] Regarding the whole series as consisting of two groups, namely, the Breccia and Conglomerate Group [No. 2], and the Sandstones and Marls Group [No. 1], it would appear from the map[2] that the Breccia and Conglomerate Group is very much thicker and more important than Group 1.

The Breccia is the remarkable assemblage of angular and subangular fragments, chiefly of igneous rocks, embedded in a red marl base. Below it we have at least three well-marked bands of calcareous conglomerate, separated by sandstones and marls, while below the lowest conglomerate we have sandstones and marls which contain some badly-preserved plant-remains at Hasbury, near Hales Owen, and also near Illey Mill. The whole series, from summit to base, is of a deep red or purplish-red colour. Below the plant-bearing beds are the yellow Hales Owen Sandstones of the Coal Measures, with a *Spirorbis*-limestone at about 50 feet below their summit. The change in colour from the yellow Coal Measures to the overlying red 'Permian' beds is abrupt and unmistakable; though, so far as I am aware, no marked unconformity has been proved between the two formations.

(2) The West Bromwich District.

In this district,[3] on the eastern margin of the coalfield, we have another large area of these red rocks, apparently consisting of representatives of those of the Clent district, but without the Breccia.[4]

Now, as early as the time when Jukes was working in South Staffordshire, these red rocks had been pierced in search of coal in several places in the neighbourhood of West Bromwich.[5]

[1] Ramsay, Explanation of Horiz. Sect. Sheet 50.
[2] Sheets 54 N.W. & 62 S.W.
[3] See Ketley, Geol. Mag. 1875, pp. 193–198.
[4] See Geological Survey map, 62 S.W.
[5] See Jukes, 'South Staffordshire Coalfield,' 2nd ed. Mem. Geol. Surv. 1859, pp. 11, 12.

At Bullock's Farm, near Spon Lane, a pit was sunk through them for 700 feet, probably beginning in beds below the lowest of the conglomerates; that is, in beds corresponding to No. 1 of the Clent section. The following is an abstract of the upper part of the section:—

	feet.	inches.
1. Red Sandstones and Marls	169	0
2. Fireclay	3	0
3. White Binds	12	0
4. Coal	0	10
5. Fireclay	3	8
6. Red Sandstones and Marls	511	6
	700	0

Below these followed ordinary Coal Measures, probably of the Middle division. The fireclays and coal passed through in this pit were essentially similar to those of the ordinary Coal Measures. We have here then a case of coal and fireclay occurring in the midst of a thick series of red rocks. From the red sandstones below the coal, casts of plants resembling *Sigillaria* were obtained.[1] Jukes considered this a true Permian coal, and not that the beds containing it were red Coal Measures. Prof. Hull, however, inclined to the opinion that they were Coal Measures.[2]

In 1870 the Sandwell Park sinking,[3] which passed through these red rocks to the thick coal, was commenced. The first 575 feet were in red and purple sandstones and marls; in these, at a depth of 369 feet, was a band of *Spirorbis*-limestone, 12 inches thick, containing *Spirorbis pusillus*. We have here a *Spirorbis*-limestone band amidst a series of red rocks at a distance of more than 200 feet above ordinary Coal Measures. This is a very noteworthy fact, for since the sinking at Sandwell a *Spirorbis*-limestone band has been observed cropping out in several places on the southern edge of the coalfield, about 50 feet below the lowest of the red rocks, and associated with blue and yellow clays and flags, and orange and olive sandstones and grits. It is, therefore, highly probable that the Sandwell *Spirorbis*-band and that of the outcrop on the southern margin of the coalfield are different bands, especially when we consider that at Sandwell there are only about 670 feet of rocks between the thick coal and the base of the red rocks, while in the Hales Owen district there are probably not less than 900 feet of strata[4] between the same horizons; and it is, therefore, quite possible that the *Spirorbis*-band found at Sandwell may be very much higher than that seen at the outcrop near Hales Owen—this latter

[1] Jukes, 'South Staffordshire Coalfield,' 2nd ed. p. 12.

[2] Hull, 'Triassic and Permian Rocks of the Midland Counties of England,' Mem. Geol. Surv. 1869, p. 12.

[3] See H. Johnson, Brit. Assoc. Rep. (Birmingham) 1886, pp. 636–638; also 'Colliery Guardian,' April 7th, 1893.

[4] Jukes, *op. supra cit.* pp. 28 & 29.

having at Sandwell been removed by denudation before the deposition of the red rocks with their *Spirorbis*-band.

In 1875 the Hamstead Pit[1] was commenced still farther east, and at a much higher horizon in the red rocks. The shaft passed through 1353 feet of red, purple, and brown sandstones and marls, the latter rich in plant-remains, before the ordinary grey Coal Measures were reached. Within this red series, at a depth of 1024 feet, there occurred a *Spirorbis*-limestone band, 8 inches thick, containing the characteristic fossil. But at the depth of only 558 feet there occurred a band, 1 foot thick, of limestone, in which no *Spirorbis* was detected; it was, however, regarded at the time by several geologists as the representative of the band previously met with at Sandwell. I have myself seen a specimen, and have no doubt that it is a *Spirorbis*-limestone band, although the particular part passed through by the shaft has so far yielded no fossils.

We have here, then, a series of 1353 feet of red rocks containing two *Spirorbis*-limestones, and rich in plant-remains which have been shown by Mr. Robert Kidston to be of Upper Coal Measure species. The Hamstead shaft began very near the top of these red rocks, and not far below the base of the Middle Bunter. The beds above the horizon of the mouth of the shaft appear in all respects similar to those in the shaft itself. There can be no doubt as to the Upper Coal Measure age of the red beds passed through in the shaft (down to 1353 feet), for the abundant fossils collected by Messrs. Meachem and Insley, and identified by Mr. Robert Kidston,[2] have shown this, especially for the lower part of the red series. The *Spirorbis*-limestones occur, one in the upper and one in the lower part of the same series. There is no reason, therefore, why we should not extend the conclusion—as to the Upper Coal Measure age of the whole series of red rocks passed through in the shaft—to the hundred feet or so of beds between the top of the shaft and the overlying Middle Bunter, and therefore to the whole of the 'Permians' of the West Bromwich district.

(3) The Wordesley District.

Crossing over now to the western side of the coalfield, we have a narrow strip of 'Permian' rocks stretching from Kingswinford to Oldswinford. When describing this tract of 'pale red calcareous sandstone and red marls' Jukes speaks as follows[3]:—'At Audenham Bank a concretionary mass of compact pale grey limestone, with a smooth conchoidal fracture, was exposed in the bank of the

[1] See F. G. Meachem & H. Insley, Brit. Assoc. Rep. (Birmingham) 1886, pp. 626, 627.

[2] Trans. Roy. Soc. Edin. vol. xxxv. (1888) pp. 317–33 5.

[3] 'South Staffordshire Coalfield,' 2nd ed. p. 184.

road lying in some red marl. It did not seem to extend far, however.'

There can be little doubt, I think, that this was a *Spirorbis*-limestone similar to those of Sandwell, Hamstead, and Wyre Forest, though it is quite possible that the fossil might not have been present in the mass that Jukes describes.

Summary.

To sum up, we find in South Staffordshire a thick series of red rocks overlying the ordinary yellow and grey Coal Measures and underlying the Trias. They consist of sandstones and marls, with calcareous conglomerates and trappoid breccia, the whole having a general red or purplish-red colour. Since the work of Jukes was published, fresh sinkings have shown that these red rocks must all be regarded as of Upper Coal Measure age, because (1) their contained fossils have an Upper Coal Measure facies; (2) they contain bands of limestone characterized by the presence of *Spirorbis pusillus*; (3) those parts of the series which have not yielded Coal Measure fossils are apparently similar lithologically to those parts which have yielded such fossils; (4) there is no known stratigraphical break between the fossiliferous and the non-fossiliferous parts of the red series; (5) the only marked breaks are at the base and summit of the red series: (6) the break at the base is locally great, but is elsewhere practically imperceptible.

III. The Wyre Forest [=Enville] 'Permian.'

Having thus briefly reviewed the evidence as to the age of these red rocks in South Staffordshire, we will now consider the same rocks and examine the fresh evidence which has lately come to light in the Wyre Forest district. This area is typical of the 'Permian' of the Southern Midlands. Prof. Hull[1] long ago urged the dissimilarity between these Southern Midland beds and those of Lancashire and Yorkshire, and gave them the convenient name of the 'Salopian Type' of Permian.

They here occur in their fullest development, and are divisible into three groups as follows:—

'Permian' of Wyre Forest [=*Enville*]. (After Prof. Hull.)

Lower Red Sandstone. [Rothliegende.]	3. Upper Sandstones and Marls		300 feet.
	2. Breccia and Conglomerate Group.	*e.* Trappoid breccia.	Variable, say 200 feet.
		d. Sandstones and marls.	
		c. Calcareous conglomerate.	
		b. Sandstones and marls.	
		a. Calcareous conglomerate.	
	1. Lower Sandstones and Marls		850 feet.

[1] Quart. Journ. Geol. Soc. vol. xxv. (1869) pp. 171–184; also 'Triassic and Permian Rocks of the Midland Counties of England,' Mem. Geol. Surv. 1869, p. 11.

Comparing this section with that of the Clent district (p. 530), we may say that, without attempting to definitely correlate the several calcareous conglomerates in the respective districts, we have an essentially similar series in both localities, except that the Upper Sandstones and Marls of the Enville district are either absent or concealed by the Middle Bunter in the Clent district. Then, again, the Lower Sandstones and Marls are apparently not so well developed in South Staffordshire.

The calcareous conglomerates and trappoid breccia are alike in both districts. Many of the red sandstones, cornstones, and marls passed through at Sandwell and Hamstead are identical in appearance with beds in the lower part of the red series of Wyre Forest.

Whatever reasons there may be, then, for regarding these 'Permian' rocks as of Upper Coal Measure age in South Staffordshire will probably apply equally to the similar series of Wyre Forest; and one may *a priori* expect that the latter, at least up to the base of the breccia, will prove to be of Upper Coal Measure age.

(1) The *Spirorbis*-limestone.

The following fresh evidence on the subject greatly strengthens these expectations.

During the month of June 1894, whilst examining the 'Permian' lower boundary in the neighbourhood of Upper Arley—a village on the eastern bank of the Severn, and 3 miles N.N.W. of Bewdley, in Worcestershire—and bearing in mind the fact that a *Spirorbis*-limestone in South Staffordshire and Warwickshire occurs in and close to the top of the Coal Measures, I thought it possible that a similar band might occur in a like position in the Wyre Forest district, although one band had already been discovered at various points around the lower margin of the Coal Measures at a short distance above the Old Red Sandstone.[1]

But an examination of the higher beds of the Coal Measures revealed no such limestone. Yet large irregularly-shaped lumps of a dark greyish-blue limestone frequently occurred in the beds of the streams flowing from 'Permian' on to Coal Measure ground, but they occurred always on the 'Permian' side of the boundary, and in association with cornstones, sandstones, shales, marls, and clays of a typical 'Permian' red, and in colour totally unlike the underlying yellow and orange sandstones and shales of the ordinary Coal Measures.

The limestone always occurred as irregularly-shaped masses from 2 or 3 inches to as many feet in length, and lying in the bottom of the stream-bed. It never appeared as a distinct bed in the banks of the stream—a fact subsequently explained by finding the limestone *in situ* interbedded between bands of marl—and hence this

[1] See D. Jones, Trans. Manchester Geol. Soc. vol. x. (1870) p. 37.

gave rise to the idea that it might possibly have been drifted from other Coal Measure areas.

This, however, was clearly not the case, as the fragments always occupied the same relative position with respect to the boundary between the red and the yellow rocks. Besides, there is an entire absence of loose blocks of any other rocks than those which occur *in situ* in the sides of the streams themselves.

The lumps first observed yielded no fossils, but the fact that the limestone showed a general resemblance in colour, texture, fracture, and in bituminous smell to the limestone from other bands, and which in other localities is fossiliferous—for example, at Hamstead—suggested that the limestone here under description would subsequently be found to contain the characteristic annelid.

A mass picked up at the ponds in the north-western part of Arley Park first showed what looked like a weathered specimen of the fossil; and I have since found fossils in the specimens from a number of different and distant localities.

The constancy in position wherein the fragments of the limestone occurred—that is, in close proximity to, but on the upper side of, the lower boundary of the 'Permian'—soon suggested the idea that really the limestone occurs on one definite horizon as a more or less continuous band. This band had not yet been discovered in an interbedded condition.

There is, however, a faulted mass of 'Permian' cut through by the Severn Valley Railway (G.W.R.) at Stanley, on the south side of Highley Station, 2 miles above Arley, which ultimately proved to contain the limestone exposed in an interbedded condition. I shall advert to this section presently in describing the course of the outcrop.

(2) General Description of the Limestone.

The limestone occurs in two varieties of colour:—(i) A dark grey, almost black, variety; and (ii) A light greyish-brown variety. Both occur in the same band, and frequently in the same block. The dark variety is perhaps richer in *Spirorbis pusillus* than the light one, is rougher in its fracture, and when freshly broken emits an unmistakable bituminous smell.

The light-coloured variety is hard, brittle, very fine-grained, and compact, breaking with a somewhat flinty fracture. It emits no bituminous smell when broken, and is apparently less fossiliferous than the dark variety.

Both kinds differ somewhat in appearance from specimens of the lower band in the ordinary Coal Measures, for example, at Arley Kings near Stourport, and at Tasley near Bridgenorth: these being apparently more earthy, less compact and smooth-fractured, and more highly charged with fossils. The lower limestone seems, moreover, to be generally light-coloured.

The only fossil that I have observed in the new band is the *Spirorbis pusillus* (Mart.), formerly known as *Spirorbis carbonarius* and *Microconchus carbonarius*.[1] Prof. T. Rupert Jones and Dr. J. W. Gregory have kindly examined specimens, and report that the fossils are all apparently *Spirorbis pusillus* (Mart.), though a slightly annulated variety.

(3) Course of the Outcrop.

We will now proceed to trace the outcrop as far as it is at present known. The limestone has been found, so far, at the following localities; most of them will be found named on the Geological Survey map, sheets 55 N.E. and 61 S.E. We will commence at the south-east of the district and proceed towards the north-west; observing that the points lie on 'Permian' ground along a line parallel to the basal boundary of the 'Permian' and at a distance therefrom depending on the amount of dip, fall of ground, and presence or absence of faults:—

1. Packet [=Parkatt] Wood, 3 miles N.W. of Kidderminster.
2. Witnell's End.
3. Belman's Cross. In place. Formerly worked and burnt.
4. Bateman's Dingle, east of Upper Arley.
5. Nash End.
6. Bainham's. In place. Formerly worked for road-stone.
7. May House. In place.
8. Little London. In place. Formerly worked and burnt.
9. Arley Park ponds. In place.
10. Bromley Brook.
11. Extons.
12. Brooks opposite Stanley Cottages.
13. Stanley Railway-cutting. In place. Interbedded.
14. Little London Brook.
15. Potter's Load.
16. Brook near Hodge Nichols, north-west of Highley [=Higley].
17. Quarry House.
18. Spadeley Rough, east of Chelmarsh.
19. Bowels Dingle, east of Allum Bridge.

Elaborate details of each of these exposures are unnecessary; it will suffice if the more remarkable are noticed.

Packet Wood.—There is a small isolated patch of 'Permian' rocks here, not noticed on the Geological Survey map. In the brook are exposed some red sandstones and marls, with loose lumps of the dark limestone. This is the only locality east of the Trimpley anticline where the limestone has been found. On the west side, the limestone occurs in a brook north of Witnell's End in the form of loose lumps.

Belman's Cross.—About 30 years ago the *Spirorbis*-limestone was worked and burnt for lime close to this place, though no traces of

[1] For palæontology of *Spirorbis*, etc., see R. Etheridge, Jun., in Geol. Mag. 1880, pp. 109 *et seqq.*

the workings now remain. Following the 'Permian' boundary, we find many lumps of the limestone in Bateman's Dingle, north-west of Popehouse; and again in the brook at Nash End.

Bainham's.—Here, in a field south of the cottage, the limestone was formerly extracted, for a depression of the surface is strewn with fragments, and the roads adjoining exhibit many pieces in use as road-stone. The limestone here occurs at the top of a low escarpment, in which is an extensive quarry of thick-bedded red sandstone, underlying the limestone. There is a thickness of between 200 and 300 feet of red rocks between the limestone and the yellow Coal Measure sandstones exposed in a pond north-east of Pickards.

May House.—The escarpment, above which the limestone occurs at Bainham's, is easily traced past May House to Little London. At the former the tenant showed me a number of large blocks of the limestone, one measuring $24 \times 21 \times 11$ inches, which had been recently dragged off the field, where it evidently crops out, in a position marked by the low escarpment.

Little London.—The limestone may be traced by fragments along the escarpment as far as Little London. In a field behind the farmhouse it was formerly wrought in openworks and burnt on the spot. Several kilns and shallow workings, all turfed over, still remain, and there are numerous lumps of the limestone strewed about the surface. Beyond this point the limestone seems to be cut off by faults.

So far we have traced the band continuously from beyond Witnell's End near Shatterford, towards Alveley, for about 4 miles. This line of outcrop is repeated by a strike-fault, no doubt the one marked on the Geological Survey map as passing near Pickards. Beginning again at the southern end of the repeated outcrop, we find the limestone at

Arley Park Ponds.—About $\frac{1}{3}$ mile north-west of Arley Castle are two small ponds, and in the western bank of the more southerly of the two the limestone is seen in place, overlain by bright red marl. The limestone seems about 13 inches thick, and consists of detached cuboidal blocks having a corroded aspect and separated from each other by wide open joints, as at Ardwick.[1] Three blocks measured had the following dimensions:—$22 \times 14 \times 13$ inches, $20 \times 14 \times 9$ inches, and $14 \times 11 \times 8$ inches. It occurs abundantly in the brook near Bromley Farm, and between Extons and the Severn, as detached lumps. In several little brooks south-west of Nether Hollies it occurs very plentifully, and the outcrop must be within a very short distance. Thence it may be traced at intervals along the east side of the valley of the Severn, through Little London Coppice, to

Little London Brook.—Here the limestone occurs as loose blocks in the stream at the top of the wood, while below it is a series, about 120 feet thick, of red marls, purple shales and flags, a foot or so of yellow and blue clay with a thin coal-seam, and hard

[1] Binney, Trans. Manch. Geol. Soc. vol. vi. (1866) pp. 39, 40.

red sandstones and cornstones. The blocks of limestone here are very large and well preserved. One piece measured $3 \times 2 \times 1$ feet. The limestone seems to disappear beyond Potter's Load Ferry, being probably cut off by faults. Crossing the Severn, the next exposure to be noticed is in

Stanley Railway-cutting.—At about $\frac{1}{3}$ mile south of Highley Station, and close to Stanley, the railway passes through a deep cutting in these red rocks. The sides of the cutting are very steep and are devoid of vegetation, the sandstones and marls continually crumbling. Along the top of this cutting, on both sides, occurs the limestone-band in place. Unfortunately, one cannot here directly estimate the height above the base of the red rocks at which the band occurs, as the 'Permian' is here cut off from the Coal Measures by faults.

The general dip of the beds in the cutting is E. at about 8°, but the surface of the ground falling at practically the same rate in the same direction, no higher beds are to be seen at one end than at the other. The following is a generalized section of the beds exposed :—

Section of Stanley Cutting.

		feet.	inches.
10.	Turf and soil	1	0
9.	Marl; red, friable	1	0
8.	*Spirorbis*-limestone	2	0
7.	Clay; mottled red and blue	1	0
6.	Sandstone; micaceous, flaggy, pink	1	6
5.	Marls; bright red	2	0
4.	Sandstone; red, flaggy	40	0
3.	Sandstone; coarse, purplish red, thick-bedded	9	0
2.	Sandstone; coarse, gritty and pebbly, brownish-red.	11	0
1.	Cornstone ..... exposed for	0	6
		69	0

Bed No. 9 is a red friable marl or hard clay, with occasional green layers. It contains small fragments of limestone and is calcareous, and probably consists to a considerable extent of the argillaceous and arenaceous constituents of the original limestone, the calcium carbonate having been largely removed by solution.

No. 8, the *Spirorbis*-limestone band, consists of a bed of large and small irregularly-shaped masses of limestone, closely packed together, the joints being filled with a mottled red and blue clay. One lump, measured as it lay *in situ*, was 27 inches long and 10 inches thick; but when loosened, it broke down into a number of smaller pieces. These contained the *Spirorbis pusillus*. Several other large fragments had rolled down on to the railway; one of these measured $15 \times 14 \times 9$ inches, another $18 \times 12 \times 8$ inches. Some of the masses present the most fantastic appearances, suggestive of the forms of certain large fungi. The surfaces, when washed, exhibit numerous projecting veins and crystals of calcite.

No. 6 is a fine-grained pinkish-red sandstone, with green decolouration-spots. No. 4 consists of beds of red sandstone, becoming more

thickly-bedded, coarser, and darker-coloured downwards. Towards the base several spheroidal masses of very hard calcareous sandstone occurred, 5 or 6 inches in diameter. These 'ballstones' are a remarkable feature of the Grindstone-beds of Alveley and Extons, which occur some distance higher up in the same series of red rocks. Nos. 3 and 2 are thickly-bedded coarse sandstones, pebbles and fragments being more frequent in No. 2. These fragments are chiefly of a pinkish limestone.

No. 1 is a cornstone, or conglomerate of small subangular and rounded fragments of limestone—usually pink, but sometimes white—and occasional fragments of siliceous rocks, the fragments being embedded in a sandy base of a purplish-red colour, and the whole cemented together into a hard compact rock by calcium carbonate.

We have, then, in this cutting what is probably the decomposing representative of a once somewhat thicker and more solid band of limestone,[1] containing *Spirorbis pusillus*, with a measured thickness of at least 65 feet of red rocks beneath; and an examination of the red rock in the immediate neighbourhood leads me to believe that the band cannot be less, and may be considerably more, than 200 or 300 feet above the top of the ordinary Coal Measures.

The limestone occurs in the triangular patch of 'Permian' north-west of Highley, for lumps of it are found in the road at Green Hall and in the brook south of Hodge Nichols. It is again met with as large lumps in some small hollows in a field west of Quarry House; as lumps in the road at Sutton; and still farther north in Spadeley Rough, east of Chelmarsh. In this direction I have followed it no farther.

Bowels Dingle.—Finally, it occurs in the form of numerous large blocks in the stream flowing through The Dingle above Allum Bridge. South-west of Astley there is a footbridge across the stream, and close to the great line of fault which repeats the whole of the 'Permian' series here. Beneath the footbridge and up the stream for some distance, large lumps of the limestone occur, and the outcrop cannot be far away. One lump was 22 inches in length. The sides of the stream show light red sandy shales with green spots, dipping about N. at 80°. Evidently the fault passes close by and has brought up the *Spirorbis*-limestone on the upthrow side. Pieces of the limestone occur farther north, at King's Nordley; and farther south, in Perryhouse Dingle.

I briefly mentioned the discovery of this limestone at a meeting of the South Staffordshire Institution of Mining Engineers on July 5th, 1894, and it was again referred to on Dec. 6th following.[2]

From such descriptions of *Spirorbis*-limestones associated with red rocks as I have been able to consult, it would appear that the newly-discovered band agrees most closely in its mode of occurrence

[1] On nodular limestones, see Rutley, Quart. Journ. Geol. Soc. vol. xlix. (1893) pp. 372–384.

[2] Trans. Fed. Inst. Mining Engineers, vol. vii. (1894) p. 577 & vol. viii. (1895) p. 356.

with some of those at Ardwick, where the limestones are frequently embedded in red clay. *Spirorbis*-limestones and red rocks also occur at Whiston near Manchester, Raw Beck near Carlisle, and Canobie on the Esk, as described by the late Mr. Binney.[1]

(4) Thin Coals in the 'Permian' of Wyre Forest.

There are now known to be several localities where thin seams of coal occur in the red rocks of this district. As already mentioned (p. 537), a thin seam of coal, probably not more than 6 inches thick, crops out in Little London Brook near Alveley. The brook flows down from Little London into the Severn. This coal is associated with yellow and blue clay, overlying at least 100 feet of red sandstones, cornstones, and marls, which are visible in the brook down to its junction with the river; and we do not reach the Coal Measures then. A little above the coal-bed, the *Spirorbis*-limestone occurs.

The coal is bright and hard, of cubical fracture, and appears to pass into a heavy black 'batt.' It is well known to the inhabitants of the locality, some of whom have occasionally collected together enough to serve as fuel.

A short distance south of Little London is The Butts, where, in deepening a well about 16 years ago, a seam of coal a foot or so thick was found. I was directed to the spot where the débris were deposited—close to a pond a little south of the house—and found some fragments of a bright cuboidal coal mixed up with pieces of lavender-coloured sandstones and blue and purple marls. This coal may be that of Little London Brook.

A little farther north of the latter brook is a road leading down to Wood Cottage, close to the river. When this road was cut some years ago, a thin pyritous coal, 6 inches thick, was cut through. No doubt this is the same as the coal which occurs in Little London Brook, a few hundred yards farther south.

There is good evidence for the occurrence of coal at a very much higher horizon in the 'Permian' series in this district, namely, in the Upper Sandstones and marls at White Cross and The Bank, south-east of Claverley. About twenty-five years ago a borehole was put down at White Cross. It commenced near the top of the 'Permian,' and passed through several 'smuts.' The following is a summarized description of the upper part of the section :—

Boring at White Cross, Claverley.

	feet.	inches.
Surface soil	1	0
Red sand with two 'smuts'	19	0
Wet sand and gravel	39	0
Brown sandy clay and rock	4	0

[1] Trans. Manch. Geol. Soc. vol. vi. (1866) p. 48.

Below these came a series of alternating red and purple marls and sandstones, 227 feet thick; and beneath this series, 'hard mottled rock with black smuts, 4 feet.' At the foot of the copy of the section is a memorandum: 'In the lane near The Bank a thin Permian coal crops out.'

About three years ago a well at White Cross was deepened, and a thin coal, 2 inches thick, was passed through. The same coal was found in a new well, recently sunk at the School House at White Cross. These statements come from men who have seen the coal.

It appears to me better to give the evidence as it stands. I have not myself seen any of these White Cross coals, but am inclined to think that they must exist.

(5) Fossils of the Wyre Forest 'Permian.'

Besides the *Spirorbis*-limestone above described, a few plant-remains have from time to time been recorded. The first announcement appears to have been made by the late Sir Andrew Ramsay,[1] a tree-stem having been found in the upper calcareous conglomerate at Four Ashes in 1854. In 1858 Mr. C. E. Roberts[2] mentioned that he had found some badly-preserved plant-remains at Alveley. No identifications have been announced. Occasionally a few badly-preserved fragments of stems are found in the Grindstone-beds of Alveley and Extons, but they have never been systematically collected or identified. We have, therefore, as yet, no help from the fossil flora in this district in support either of the Coal Measure or Permian age of these red rocks.

IV. Classification of the Wyre Forest 'Permian.'

Having now, as I think, established the fact of the occurrence in these red rocks of at least one *Spirorbis*-limestone band and of thin, but nevertheless true coal-seams, our attention may be directed to the bearing of these new facts on the classification of the red rocks in which the limestones and coals occur.

Let us consider first the Lower Sandstones and Marls—No. 1 of the Wyre Forest Section (p. 533). These were regarded by Murchison as representative of the Rothliegende of Germany. He also suggested that the overlying calcareous conglomerates represented the Zechstein. The former of these two theories has been accepted and retained, while the calcareous conglomerates of Alberbury, Coton, and The Bowels, etc., are now regarded simply as more or less local and inconstant deposits indicative of the proximity of land; which land consisted largely of Carboniferous Limestone and to some extent, apparently, of Upper Coal Measures also, inasmuch as occasional pebbles of *Spirorbis*-limestone, containing the fossil, occur in the conglomerates.

[1] Quart. Journ. Geol. Soc. vol. xi. (1855) p. 189.
[2] 'Geologist,' 1858, p. 253.

(1) Stratigraphical Relations.

It is to be noticed that Murchison states[1] that in many places these Lower Sandstones and Marls may be seen to pass down conformably into Upper Coal Measures. On the other hand, Ramsay was of opinion that there was a considerable unconformity between the 'Permian' and the Carboniferous System generally.[2] Probably both observers were in part correct; the floor on which the 'Permian' beds were being laid down was probably undergoing a corrugation, both on a large and small scale. Thus, while in one part of the area continuous and uninterrupted deposition took place, Upper Coal Measures graduating into 'Permian,' yet in another part the Upper Coal Measures and indeed still lower members of the Carboniferous and older rocks may have been elevated into ridges, more or less eroded, and then sunk beneath the red sediments. Hence we cannot well argue as to the affinities between the 'Permians' and Coal Measures from this point of conformity or unconformity, as in some places there appears to be conformity, and in others a certain amount of break.

So far as the Wyre Forest district is concerned, Murchison was of opinion that the Upper Coal Measures and 'Permians' are conformable to each other, and quotes a section at Chelmarsh as showing the passage of one into the other. But in the neighbourhood of the Trimpley anticline there is some slight evidence of unconformity.

It is important to remember, too, that it is tolerably certain that in the Coalbrookdale district there is a vastly greater break between Middle Coal Measures and Upper Coal Measures[3] than between the latter and the 'Permian.' In some places the Upper Coal Measures rest upon the highest, and in other places upon the lowest of the coal-seams of the Middle series.

(2) Lithological Characters.

With regard to lithological characters the 'Permian' rocks possess several which separate them from the underlying Coal Measures. They are, on the whole, red or reddish-purple in colour —often of a bright salmon tint; and they contain beds of calcareous conglomerate (shingle-beaches of limestone and other pebbles) and trappoid breccia, which do not appear to resemble anything found in the underlying Coal Measures. But, of these points of difference, perhaps that of colour is the most important. The general change in colour is undoubtedly the strongest reason for separating the Red

[1] Proc. Geol. Soc. vol. ii. (1835), p. 117; also 'Silurian System,' 1839, pp. 92, 131, 132.

[2] Quart. Journ. Geol. Soc. vol. xi. (1855) pp. 187, 204.

[3] See Marcus Scott, Quart. Journ. Geol. Soc. vol. xvii. (1861) p. 457; also Daniel Jones, Geol. Mag. 1871, p. 200.

Rocks from the underlying grey, yellow, and olive-coloured series below.

The red colour of some Upper Coal Measures has been referred in several cases to a soaking downwards of colouring-material from beds subsequently deposited, and not to a deposition of colouring-matter carried on contemporaneously with the deposition of the sediment. How far true this may be in other districts I am unable to say. In the Wyre Forest district there are, I think, several facts which go against such an idea:—

(*a*) The base of the red rocks appears to be a definite horizon, and seems to have been so regarded by the Geological Survey. If this staining had percolated downwards, why does it apparently stop on reaching one definite horizon? It might be expected to cut across the bedding and go deeper in some localities than in others.

(*b*) We might perhaps expect to find occasional masses left unstained, and the intensity of staining might be expected to bear some relation to the fineness or coarseness of texture of the material; but it is not proved that such is the case.

(*c*) Green decolouration-spots commonly occur in the fine-grained sandstones, shales, and marls of these red rocks. These are supposed to be due to the deoxidizing effects of carbonaceous matter embedded in the sediment during its deposition, and which, whilst slowly decomposing, has reacted on the surrounding matter and bleached it. It is probable, therefore, that the colouring-matter was present during the bleaching, and consequently before the carbonaceous matter was destroyed. This destruction would probably commence as soon as the fragment was embedded; hence the colouring-matter of such rocks must be regarded as original and not as secondary. At least, it is difficult to imagine any process of subsequent staining which could succeed in leaving small unstained spherical masses, usually less than an inch in diameter, apparently differing in no respect of texture from the surrounding mass.

However this may be, it is not essential to our purpose, as many beds of the Keuper Marls and Sandstones contain green spots similar to those in the red rocks immediately overlying the Coal Measures; and it has never been suggested, I think, that the staining of the Keuper Marls and Sandstones is a secondary effect, inasmuch as there is no higher red series from which their colour could have been derived.

It seems then that, whatever the true age of these red rocks, we must consider their colouring as contemporaneous, and not as derived from any higher formation.

Since writing the above, I find that the Rev. A. Irving has adduced other arguments in support of the 'contemporaneous colouring' theory [1].

It may here be remarked that the occurrence of a *Spirorbis*-

[1] Geol. Mag. 1882, p. 274.

limestone so clearly associated with red rocks is very suggestive of the 'continental' rather than marine habitat of *Spirorbis pusillus*.

If it be granted that the red colouration is original, it can only be the reflection of external changes in the conditions of deposit. We have here, then, a strong character which allies the beds under discussion with the whole of the true Permian and Trias.

(3) Analogies from other Districts.

It has of late years been strongly urged by several observers that colour must be regarded as of little importance in deciding the affinities of beds. Hence series of red strata formerly considered as 'Permian' have in several districts been entirely relegated to the underlying Coal Measures, on the evidence of the presence of Coal-Measure fossils, or of seams of coal or *Spirorbis*-limestone, or the absence of any marked break at the base of the red series.

Thus the red clays of Walsall Wood and Essington in South Staffordshire, at first regarded as Triassic, then 'Permian,' were subsequently regarded by Jukes as Coal Measures.[1]

We have seen that the 'Permians' of Hamstead have been shown by the fossil flora to be of Upper Coal Measure age. Again Mr. W. T. Aveline[2] points out that the Lower Red Sandstone of Sedgwick (Rothliegende of Murchison), with its coal-plants and coal-beds, has generally proved to be Coal Measures or Millstone Grit, 'and the Permians of Staffordshire and Warwickshire are now said to be Upper Coal Measures of a red colour,' although he gives no evidence in support of the statement And again, the same observer, as pointed out by the Rev. A. Irving,[3] after a re-survey of the southern end of the Derby and Nottingham Coalfield, gives up to the Coal Measures the red sandstones and shales which lie conformably on the Coal Measures, and which were formerly regarded as Lower Red Sandstone, *i. e.* 'Permian.' The reason for the change seems to be that there is a greater break above than below the doubtful beds.

The Rotherham, Ackworth and Pontefract Red Rocks, first regarded as Coal Measures, then 'Permian,' are now considered to be Coal Measures.

The Plumpton Rocks and Knaresborough Grits are now regarded as Millstone Grit,[4] and not 'Permian,' as was at first supposed.

Moreover, there are other masses of red rocks which have long been considered Upper Coal Measures, and which apparently resemble the Lower Sandstones and Marls of the Wyre Forest district in containing *Spirorbis*-limestones and thin coals, and in

[1] 'South Staffordshire Coalfield,' 2nd ed. Mem. Geol. Surv. 1859, pp. x. & 102.
[2] Geol. Mag. 1877, p. 156.
[3] *Ibid.* 1882, p. 221.
[4] J. Clifton Ward, Quart. Journ. Geol. Soc. vol. xxv. (1869) pp. 291–297.

having a general red colour: such as the upper part of the section at Ardwick, given by Mr. Binney, and also at Whiston, Raw Beck, Canobie, and Catrine.[1]

[The Whitehaven Sandstone of the Cumberland Coalfield, about the systematic position of which some doubt formerly existed—on account of its red colour—has been for some time assigned to the Coal Measures.[2] In the last number of this Journal (p. 235) Mr. J. D. Kendall announces that a *Spirorbis*-limestone band has been discovered in this sandstone.

In the Fifeshire Coalfield we find a thick series of red beds overlying the ordinary Coal Measures. Messrs Binney and Kirkby conclude that they are probably of Upper Coal Measure age. They contain coal-seams and Coal Measure fossils, but no *Spirorbis*-limestones.[3]

At Conisborough pottery in the Yorkshire Coalfield the red beds containing Coal Measure plant-remains have been referred to the Upper Coal Measures.[4]

Again, it must be carefully borne in mind that the occurrence of a slight unconformity at the base of a series of beds is not in itself sufficient ground for entirely separating that series from the one beneath. We have already seen that in Coalbrookdale the yellow Upper Coal Measures are highly unconformable to the Middle Coal Measures. In the Leicestershire Coalfield the yellow Upper Coal Measure sandstones of Moira and Newall are unconformable to the underlying Middle Coal Measures.[5]

In the Lanarkshire Coalfield the red Coal Measure sandstones of Hamilton and Blantyre are slightly unconformable to the beds below.[6]—July, 1895.]

There is plenty of precedent, therefore, for placing the Lower Sandstones and Marls of the Wyre Forest 'Permians' among the Upper Coal Measures.

Supposing then that we relegate these Lower Sandstones and Marls to the Upper Coal Measures, what is to be said about the groups 2 and 3 (p. 533)—that is, the Breccia and Conglomerate Group, and the Upper Sandstones and Marls? Are these all to be regarded as Upper Coal Measures also? If so, we have apparently no true Permian here at all. If groups 2 and 3 cannot be both regarded as Upper Coal Measures, where are we to draw the base of the true Permian here, and what constitutes the true Permian of the district?

[1] Trans. Manch. Geol. Soc. vol. vi. (1866) pp. 38 *et seqq.*

[2] Hull, 'Coalfields of Great Britain,' 3rd ed. 1873, p. 215. But see Binney, Trans. Manch. Geol. Soc. vol. vi. (1866) pp. 51–53

[3] Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 245.

[4] 'Geol. of Yorks. Coalfield,' Mem. Geol. Surv. 1878, pp. 479–480.

[5] Hull, 'Leicestershire Coalfield,' Mem. Geol. Surv. 1860, p. 56.

[6] Hull, 'Coalfields of Great Britain,' 3rd ed. 1873, p. 274.

So far as we at present know, the case seems to stand as follows:—The Calcareous Conglomerates and Trappoid Breccia of the Middle Group are variable in thickness and horizontal extent, and in some cases altogether disappear. With regard to the Upper Sandstones and Marls, which may be seen at various points between Enville and Claverley where not concealed beneath drift, we must be more cautious. It has been stated that they differ in no essential respect from the Lower Sandstones and Marls. We have already (p. 540) seen that there is good evidence for the occurrence therein of thin coals. But an examination of the exposures along the course of Philley Brook leads me to believe that these beds show a much closer general affinity to the overlying Lower Bunter than do the Lower Sandstones and Marls.

However, accepting the evidence for the coals at White Cross, the conclusion seems to be inevitable, that whatever position we assign to these 'Permian' beds, we must treat the whole series as an individual group; and whatever name we give to the Lower Sandstones and Marls, we must also give to the Conglomerate and Breccia Group, and to the Upper Sandstones and Marls.

We have next to consider whether they should be regarded as:—

1. Red Upper Coal Measures.
2. Rothliegende or Lower Permian.
3. Passage Beds from Upper Coal Measures to New Red Sandstone (=true Permian and Trias).

Judging by precedent, they may well be called 'Red Upper Coal Measures.' But perhaps we are not entitled to entirely neglect the one great fact of their constituting a practically unbroken red series 1500 feet thick. Were it not for the presence of *Spirorbis*-limestone and thin coals, and if there were a more pronounced break at the base of the series—if, moreover, we could get rid of the evidence of the fossil flora obtained from the same series at Hamstead and Sandwell in South Staffordshire—we might well retain the old name of 'Lower Permian' or Rothliegende.

In the light of the evidence herein described, however, we cannot fail to see that in the Wyre Forest district, at least, the conditions which prevailed during the period of the Yellow Upper Coal Measures—while sandstones, shales, pyritous coals, and *Spirorbis*-limestones were deposited—continued with little interruption, but with a gradual change, till the advent of the Trias. This gradual change is marked by the diminution in the number and thickness, and ultimate cessation of the coal-seams, and the cessation, after a while, of the formation of *Spirorbis*-limestones. At the same time, the change in colour was possibly caused by the closing of the area of deposit, although this closing did not at once prove fatal to the *Spirorbis*, which flourished and formed a limestone, in spite of the changed conditions, at least 200 or 300 feet above the base of the red rocks.

It seems, then, that we have in these beds a gradual passage from the Yellow Upper Coal Measures of the Wyre Forest Coalfield into the Trias, with its absence of coal-seams and *Spirorbis*-limestones, its paucity of plant-remains, its conglomerates and breccias, and its universally prevailing red colour.

I venture, therefore, to submit that the Wyre Forest [=Enville] 'Permians' would be better described as Coal Measure Passage Beds; that is, a series of beds exhibiting the gradual passage of Coal Measure characters and conditions into those of the New Red Sandstone, in this district represented by the Bunter and Keuper. As we have seen, at Bridgenorth there is a great overstep of the Lower Bunter across the 'Permian' strata. It is, therefore, quite possible that still higher beds come in between the Upper Sandstones and Marls of Claverley and Bobbington and the Lower Bunter, in a north-easterly direction, which may prove to be more allied to true Permian strata as developed in other districts—for example, the North-east of England.

V. Conclusions.

We have now passed in rapid review the evidence which has been of late years accumulating in South Staffordshire as to the very close relationships which exist between the beds usually described as 'Lower Permian of Salopian type' and the Upper Coal Measures.

The evidence of the fossil flora and the *Spirorbis*-limestones and coal-seams in South Staffordshire, together with that of the *Spirorbis*-limestone and coals in the Wyre Forest district, leads us to regard the associated red rocks as Upper Coal Measures, exhibiting a gradual passing away of Coal-Measure characters and conditions and a gradual oncoming of those of the New Red Sandstone (=true Permian and Trias); while in the absence of any palæontological evidence of the presence of a Permian fauna and flora these Passage Beds must be regarded as much nearer the Coal-Measure than the Permian or Triassic end of the transitional period.

How far these conclusions, if they appear reasonable from the evidence afforded in the two districts specially considered, may be applicable to the other areas of Salopian 'Permian' rocks, may at present be left an open question. But it should be pointed out that, so far as our present knowledge goes, the 'Permians' of Anglesey, Denbighshire, Lebotwood, Shrewsbury, Coalbrookdale, Wyre Forest [=Enville], South Staffordshire, Warwickshire, Leicestershire, and North Staffordshire are all essentially similar; and there are now very good *a priori* reasons for expecting that—when all these areas shall have been explored by mining and other operations even to so small an extent as is the case in South Staffordshire—additional evidence of a similar nature will be forthcoming from these districts also.

Of course, it is quite possible that further investigations in these

districts may bring to light some evidence of Permian affinities, but at present no such proofs exist; for the half-dozen fragmentary plant-remains from the Warwickshire 'Permian' of Exhall, Allesley, and Meriden, of the identity of which some doubt appears to have been expressed, can hardly be regarded as of much evidential value; nor is *Strophalosia* an exclusively Permian genus.

In conclusion, I would urge other observers in these Salopian 'Permian' districts to carefully look out for coal-seams, plant-remains, and especially *Spirorbis*-limestones, as all these may henceforth be expected to occur in the lower parts, and possibly throughout the whole of this red pre-Triassic series.

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40. *On* Overthrusts *of* Tertiary Date *in* Dorset. By A. Strahan, Esq., M.A., F.G.S. (Read June 5th, 1895. Communicated by permission of the Director-General of H.M. Geological Survey.)

[Plates XVII. & XVIII.]

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I. Introduction.

The intensity of the earth-movements which have thrown on end and inverted the Secondary rocks of Dorset, and the magnificent dissection of the structures in the sea-cliffs, have attracted attention for many years past. The first to give an accurate account, and to speculate on the causes of the position of the strata, was Webster in 1816[1]; though admirable in his description and in his pictorial representation of the facts, he failed in his endeavour to explain them, and was in this respect improved upon by Conybeare and Phillips in 1822,[2] and by W. B. Clarke in 1837.[3] In 1830 Buckland and De la Beche read their paper on the Geology of Weymouth, etc.,[4] and gave an account of the principal faults, but did not correctly distinguish those that were formed before the deposition of the Gault from others that were produced at a later date. In 1848 a cutting made for the Dorchester and Weymouth railway revealed unsuspected complications in the great Ridgeway disturbance, which were described with great accuracy by Weston in 1848 and 1852,[5] while additional light was thrown upon the subject by the publication in 1850 of the Geological Survey map, Sheet 17, in the preparation of which Bristow received great assistance from the Rev. O. Fisher. Further speculations on the age of some of the disturbances were made by Prof. Prestwich in 1875,[6] and the existence of two distinct sets of movements was

[1] See Englefield's 'Isle of Wight,' pp. 164–168, pls. xxvi. & xxvii.
[2] 'Outlines of the Geology of England and Wales,' pp. 111, 112.
[3] Mag. Nat. Hist. new ser. vol. i. p. 461.
[4] Trans. Geol. Soc. ser. 2, vol. iv. pt. i. (1835) p. 1.
[5] Quart. Journ. Geol. Soc. vol. iv. p. 245, and vol. viii. p. 110.
[6] *Ibid.* vol. xxxi. p. 43.

pointed out by Mr. Hudleston in 1881 and 1889.[1] In 1876 M. Barrois did much towards elucidating the effect of the Isle of Purbeck disturbance by identifying the Upper Chalk zones above and below the fault at Ballard Point.[2]

In 1888 the new Ordnance Survey maps on the scale of 6 inches to the mile having become available, and the geology of the Isle of Wight having been recently re-surveyed on that scale, it was decided by the Director-General of H.M. Geological Survey to continue the re-survey westwards into Dorset. This work was completed, as far as the Secondary rocks south of the Hampshire Basin were concerned, in 1890.[3]

During these and the preceding years Mr. Clement Reid had been engaged in working out the structure along the South Coast east of the Isle of Wight, and had succeeded in tracing out a number of post-Cretaceous folds ranging generally east and west, and presumably synchronous with the later group of disturbances about to be described. In addition to these he found at Eastbourne a number of small overthrusts in Chalk, Greensand, and Gault which seem to belong to the same era, though they trend about N.N.E., and therefore cross the others obliquely. These disturbances, which seem not to have been previously noticed, will be described by him in due course.

The results of our observations on the physical geography of the South Coast have been already brought forward to a certain extent in the 2nd edition of the Memoir on the Isle of Wight. The further evidence obtained in carrying the work westwards will be given in full detail in a Memoir on Purbeck and Portland which is now in preparation, and in which, besides stratigraphical details, much attention has been devoted to the disturbances and to the share that they have taken in producing the existing physical features. In the present paper I propose to give briefly the principal conclusions to which I have been led with regard to the structure of South Dorset.

II. Grouping and Description of the Disturbances.

The disturbances can be at once divided into two great groups, the one formed before the deposition of the Upper, but after that of the Lower Cretaceous rocks, and the other being of Tertiary (mainly Miocene) date. To the former belong the anticline of Osmington Mills, the syncline of Upton to the north of it, and the anticline of Chaldon, farther north again, the last-named, however, having been much changed by later movements. In the same group also I place

[1] Proc. Geol. Assoc. vol. vii. p. 176, and vol. xi. p. xlix (Excursion to Weymouth).

[2] 'Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande,' pp. 102, 103, pl. iii. fig. 7.

[3] The 6-inch geological maps of the Dorset Coast and of the Isle of Wight have been mounted as wall-maps and suspended in the Museum of Practical Geology.

the Broadway anticline and the Upway syncline to the north-east of it (see map, Pl. XVII.). Farther west, and also of the earlier age, are a large fault at Abbotsbury, a syncline at Litton Cheney, and a large fault at Chilcombe, together with other minor folds and dislocations.

The latter or post-Cretaceous group includes the great Isle of Purbeck fold (which is the continuation of the Isle of Wight disturbance), the Ringstead fold, the Chaldon and Ridgeway disturbances, and lastly the Litton Cheney fault.[1]

As a consequence of the earlier set of movements, the Upper Cretaceous rocks rest with a conspicuous unconformity upon the upturned Jurassic and Wealden strata, coming into contact with each in quick succession. On the top of this unconformity and of the disturbances which caused it were superimposed the later movements, leading to the strange complications which it is my object to attempt to unravel. For this purpose it will be best to eliminate first of all those folds which we know to belong to the later group by the fact that they affect Upper Cretaceous rocks.

(1) Post-Cretaceous Disturbances.

(*a*) The Isle of Purbeck Fault and Fold.

This disturbance commences east of the Isle of Wight and dies away in Weymouth Bay.[2] At Ballard Point, near Swanage, it strikes the coast at right angles, giving rise to the remarkable section figured by Webster. The section in Pl. XVIII. fig. 1 gives the cliff-sections, in part reduced from photographs, and at the same time shows the supposed structure below the sea-level and above the present land-surface. In this and the other sections prominence is given to the base of the Upper Cretaceous rocks by a dark line.

The cliff has been so accurately described by Webster, Clarke, and others that it will be unnecessary to repeat more than the salient features. It will be noticed that the dip increases regularly on the south side until it reaches verticality near and under the fault. This, with a knowledge of the thickness of the various subdivisions, renders it possible to restore the curve of the monocline upwards. The fault itself exactly follows a bedding-plane in the curving Chalk above, but cuts across the edges of the vertical strata beneath; it therefore originally ran in part of its course along, but in other parts across the bedding. The position of the *Belemnitella* (*B. mucronata* and *quadrata*)-zones proves that the movement along the fracture was the reverse of that of a normal fault. For the curving strata above the fracture must have been thrust

[1] A disturbance of post-Cretaceous age at Winterborne Abbas falls nearly into the line of the Litton Cheney fault, but lies outside the area which I have examined.

[2] In the 'Geology of the Isle of Wight,' Mem. Geol. Surv. 2nd ed. 1889, p. 239, the anticline of the Isle of Wight is said to commence off the coast of Devon. I take this opportunity of correcting that statement, for which I alone was responsible.

over the vertical strata below it, and not depressed relatively to them, as would be the case in a fault hading to the downthrow. The inference follows that the curve in the strata above the fault was part of the lower limb of the monocline, and that it has been brought up from that position, and placed as we now see it, partly against and partly over the central and vertical portion of the monocline.

The extent of the movement along the fracture could be estimated if we could determine the depth below sea-level of the lower limb of the monocline. In filling in the structure below sea-level in the section (Pl. XVIII.), I have represented the vertical strata as curving to horizontality at as small a depth as seems probable, and the extent of the thrust as being about 400 feet. If the vertical strata do not turn so soon as represented, the thrust must be greater. But we seem to reach a limit in this direction, for the following reason. The vertical strata and the thrust-plane diverge downwards rapidly, the thrust-plane tending to curve away northward as it descends. Unless the strata curve also and still more quickly, so as to become parallel to and meet the thrust, we should be compelled to assume that Tertiary strata come in between the two, in their proper position next to the vertical *Belemnitella*-zones. There would thus be a lenticular mass of Tertiary rocks embedded in the heart of the Chalk. Theoretically this is no more impossible than that the *Belemnitella*-zones should so occur, but it would mean that the thrust-plane in some part of its course left the Chalk and traversed the lower Tertiaries, which is not probable. That the thrust-plane should in part have followed the bedding and in part cut across it seems to follow from the nature of the movement along the plane. It would originate as part of the hinge-like movement of each bed over its neighbour, which must take place in every fold. Subsequently it played a more important part in relieving a strain which was tending to produce inversion, and in so doing cut across the loops of the S, so as to admit of sliding on a large scale.[1]

Section 2 (Pl. XVIII.) is drawn across the same line of disturbance at Lulworth Cove, 14 miles farther west. The observations on which it is founded were made in the east of the Cove, but the section has been reversed to facilitate comparison with the others. It illustrates a modification in the curves of the monocline, but more especially shows how the soft strata have been squeezed out of one part of the fold, where the compression has been greatest, and packed away in another part, where there has been a tendency to gape.

The Portland and Lower Purbeck strata have a normal dip of 20° to 30°, but the Lower Wealden are inverted 20° beyond verticality. The bedding of the one formation therefore stands at right angles to that of the other, and would meet it, if prolonged,

[1] In the 'Geology of the Isle of Wight,' Mem. Geol. Surv. 2nd ed. 1889, p. 241, a somewhat similar thrust is described as the most probable explanation of the absence of certain beds at Ashey.

at a little over 100 feet below sea-level, indicating a region of compression at that depth. Upwards, on the other hand, the two formations diverge equally rapidly, indicating a tendency to gape. The cliff intersects parts of both regions, and shows the behaviour of the more yielding strata under the peculiar circumstances. The beds affected are the Upper and Middle Purbeck from the Cinder Bed upwards; they consist of shales and clays with numerous rock-bands, most of which are easily recognized. At the foot of the cliff these harder beds are crowded together, the softer partings having been squeezed out, but at the same time a very sharp little anticline in the Cinder Bed just shows above the foreshore. Traced upwards in the cliff this little fold gains size in every succeeding zone, until in the *Unio*-beds it becomes a large inverted Λ. The result of these movements has been that strata originally 200 feet wide have been packed away in a width of about 100, the loss of space in the direction of the bedding-planes being compensated for by a gain in a direction at right angles to them. In this case the strata of the Λ-fold have moved not less than 100 feet relatively to the Lower Purbeck, not along any one fracture, but by a gliding-movement along the bedding-planes. The well-known contortions in the Upper and Middle Purbeck of Stare Cove seem to have originated in the same way.

The inversion of the Wealden Beds diminishes northwards through verticality to a normal dip of 50° and 45° in the upper part of the formation. The Upper Chalk, however, must be more highly inclined than this, for both east and west of the line of section it is either vertical or inverted. Hence follows the irregularity of the curve of the monocline shown in the section. Of the Isle of Purbeck fault little is known here, except that nearly horizontal beds (Tertiary and Chalk) occur in close proximity to vertical Upper Chalk.

At Dungy Head, which lies about midway between Sections 2 and 3, the cliff intersects the region of compression which is partly seen at Lulworth. The Portland Stone and Lower Purbeck dip steeply towards Middle Purbeck rocks in the upper part of the cliff, but at the foot of the cliff the Lower Purbeck strata are squeezed out to a mere line, so that the Cinder Bed comes into contact with the Portland Stone. Between the Middle Purbeck and the Wealden there is also a squeeze-out, for the Upper Purbeck and an unknown amount of the Wealden have disappeared. Some of the Gault has suffered in a similar manner.

Section 3 (Pl. XVIII.) is drawn through the eastern end of the Chaldon anticline and thence southwards through the Durdle promontory, where the Isle of Purbeck fold attains its greatest intensity. The strata have not only undergone wholesale inversion and compression, but have been horizontally fractured and shifted in a manner not seen elsewhere.

The Portland Stone and Lower Purbeck stand nearly vertically; but most of the Middle Purbeck (excepting the Cinder Bed), all the Upper Purbeck, and some of the Wealden have been squeezed out.

From this point northwards to the fault all the beds are turned over 20° to 30° beyond verticality. The Isle of Purbeck fault cannot be seen, but inverted and vertical Upper Chalk is succeeded northwards so abruptly by nearly horizontal Upper Chalk and Tertiary sands that there must be a fracture of some kind.

In approaching this promontory from the east, the observer passes along the foot of a cliff of inverted Upper Chalk, a projection from which, opposite Man-o'-War Rock, shows the Corfe marl-bed [1] and just reaches the Upper Greensand. In the east side of this projection the Upper Chalk, almost at the horizon of the Chalk Rock, is intersected by a nearly vertical crush-plane, bounded by sharp but curving sides, and about 10 to 20 feet wide. This crush after running along the foot of the cliff for about $\frac{1}{3}$ mile, crosses the Durdle promontory, and is then lost to view under the shingle, keeping close to or at the horizon of the Chalk Rock for the whole distance. The Chalk, everywhere more or less brecciated and hardened, has been completely ground up and recemented within this crush; a black flint-nodule, for example, on the east of the projection mentioned above, has been not only crushed to powder, but drawn out into a black streak like coal-dust. Other flints close by are broken but not disarranged, and some are not even broken. The compression hereabouts has been so great that the outcrop of the Portland Stone in the Man-o'-War Rock is only about 270 feet from that of the Chalk Rock in the cliff, though there should be about 1100 feet of strata between the two. It is surprising under such circumstances to be able to recognize most of the well-known subdivisions, even the Corfe marl-bed being easily detected.

The horizontal fractures to which I have alluded occur at fairly regular intervals one above the other, on either side of the Durdle promontory; but the principal runs near the foot of the cliff on the western side, its course being conspicuously marked out for upwards of 150 yards by a line of caves. These slide-planes are not actually horizontal, but rise northwards at a gentle angle, and in each one the roof has been pushed up over the floor for a distance varying from 4 to 12 feet or possibly more. The result has been to increase the inversion of the strata; thus the Corfe marl-bed, in which three of these slide-planes can be detected on the western side of the promontory, is carried some 20 yards farther by them than by inversion alone. It will be seen by Section 3 (Pl. XVIII.) that the upper limb of the monocline was upheld on its northern side by little more than soft Tertiary strata, whereas behind the lower limb lay the whole thickness of the Chalk. The conditions would seem, therefore, to have been favourable for the production of an overthrust, as soon as the inverted fold had come into existence. The small slide-planes described may be regarded as the first stage in such an overthrust, which might (if continued) have placed inverted Chalk on the top of the Tertiary strata of Newlands Warren.

[1] A thick bed of marl, which occurs in the upper part of the Lower Chalk in the Isle of Purbeck and for some miles westwards.

The Isle of Purbeck fault passes out to sea a mile farther west, but cuts the cliff so obliquely that the section can be scarcely interpreted. It can be seen, however, that the strata north of the fault become horizontal within 30 yards, and then assume a south-easterly dip, corresponding with that shown in the section. Here we see the last of the great Isle of Wight and Isle of Purbeck disturbance, for no trace of it exists in the Weymouth promontory. It must therefore die away in Weymouth Bay somewhat abruptly, and not far from the point of its greatest intensity.

(*b*) The Ringstead post-Cretaceous Movement.

Disturbances belonging to both the earlier and later groups occur near Ringstead. The one now referred to throws the Chalk and Greensand up at angles of 40° to 75°, for a distance of less than a mile at South Down Farm. It possesses the usual form of the folds of this age, namely that of an arch with a steep plunge down to the north, and, moreover, makes its appearance a little north of the neighbourhood where the Isle of Purbeck fold dies away, a relation that commonly holds between these disturbances. The Ringstead post-Cretaceous disturbance lies very nearly in the line of the Osmington Mill anticline, which, however, belongs to the earlier group (see map, Pl. XVII.).

(*c*) The Chaldon and Ridgeway Fold and Overthrust. (Pl. XVII.)

This great disturbance is second in importance only to that of the Isle of Purbeck. It commences as an arch in the Upper Cretaceous rocks, which after rising gently from the south plunge down north at 40° to 50°. The crest of the arch having been denuded away, an irregularly oval inlier of the floor of Wealden and Purbeck Rocks, on which the Upper Cretaceous strata were unconformably laid down, has been exposed. In these rocks also an anticlinal arrangement prevails, which, however, has resulted from a combination of the later with an earlier disturbance.

The Gault and Greensand come into contact with different parts of the Wealden and Purbeck group in the inlier in consequence of the discordance that resulted from the earlier disturbance, and not necessarily implying a fault. The fold keeps its course due west for about 2 miles and then dies away in the Upper Chalk north of Holworth. But almost immediately the great Ridgeway fold and fault starts into existence about 400 yards farther south. Here the evidence of displacement is clear, for different horizons of the Chalk come into contact with the Purbeck rocks, the whole of the Gault and Greensand being cut out. The Upper Cretaceous subdivisions all re-appear in normal sequence farther west, though for a short distance only, and even here have probably moved more or less over the underlying Oolitic strata. No such doubt exists west of Sutton Poyntz, for the regular run of the beds is suddenly

interrupted by a curving fracture which cuts through Greensand, Lower Chalk, and Middle Chalk, and then curving round again intersects these beds, thus taking what may be called a 'bite' out of the Upper Cretaceous base. The Upper Greensand then runs through Bincombe, but immediately west of the village is cut out again, nor does it re-appear, except for a few yards east of Ridgeway, for about 6 miles. The short outcrop at Bincombe is probably, therefore, also faulted against the Oolitic rocks. Throughout all the length of this disturbance the Upper Cretaceous rocks dip at a steep angle (60° to 80°) near the line of fault, but quickly flatten out north of it.

So far its irregular course, varying throw, and habit of keeping at or close to the base of the Upper Cretaceous escarpment merely suggest that the Ridgeway disturbance differs from a normal fault, but in the underlying Oolitic platform complications occur that cannot be explained on the theory of its being of this character. The difficulty lies in the occurrence of Oxford Clay at Ridgeway, and of an inlier of Oxford Clay, Cornbrash, and Forest Marble at Bincombe, which was first detected and shown on the map by H. W. Bristow.

It will be noticed that a Portland Stone outcrop commences at the curving fault near Sutton Poyntz, the rock dipping at a high angle northwards close to the fault, but becoming horizontal at a short distance from it, so as to form the plateau of Chalbury and the neighbouring hill. A similar structure prevails west of Bincombe, the outcrop of the steeply-inclined Portland Stone forming a straight scarp parallel to the fault. This scarp should join the corresponding outcrop east of the village, instead of which it abruptly terminates, and we step from it on to Cornbrash. We follow the Cornbrash with Oxford Clay above it and Forest Marble below it for about 400 yards, and then equally suddenly pass on to nearly horizontal Kimmeridge Clay, surmounted by Portlandian rocks a few yards farther on. The Cornbrash, which here appears at the surface, should in normal sequence occur at a depth of about 1900 feet.

About a mile to the west occurs the well-known Ridgeway cutting, in which the Oxford Clay is again seen in an altogether unexpected position. The section was figured and accurately described by Weston when the cutting was fresh, and enough can still be seen to check his account. The main facts are these:—The Portland, Purbeck, and Wealden Beds occur in proper sequence, the first-named dipping north at 20°, but the others increasing in inclination up to 60° near the fault, and at the same time swinging round so as to dip N.E.[1] The Chalk on the north side of the fault dips north at 85°, and though its base has not been seen in the cutting, it must lie at no great depth below it, for the Upper Greensand rises into view 300 yards east of the railway. Between the Wealden Beds and the Chalk lies a vertical rib or 'dyke' of clay, containing

[1] The section runs here nearly along the strike, and therefore does not show this high dip.

numerous Oxford Clay fossils [1] and some blocks of Cornbrash. The 'dyke' where crossed by the cutting is about 20 or 30 yards wide, and was followed down in shafts to a depth of 50 feet, where it still kept the same character, and was still cut off northwards by a clean, nearly vertical wall of Chalk.[2] Between the middle part of the Wealden group and the top of the Oxford Clay, there would, in a normal sequence, be a thickness of about 2000 feet of strata.

The explanation hitherto given of the appearance of the Oxford Clay at Ridgeway depended on the existence of the two systems of disturbance to which I have already referred. Mr. Hudleston remarks:—'The most probable supposition is that there exists a double fault here, and that one of the faults is of pre-Cretaceous age, pointing to extensive pre-Cretaceous denudation. Thus the base of the Upper Cretaceous (here the Upper Greensand) at Ridgway may really rest upon Oxford Clay, as is represented to be the case at the inlier of East Compton, a few miles to the north-west. In this case the Wealden-Purbecks would not pass under the Chalk, as they are bound to do, if this were a simple fault hading to the downthrow in the ordinary manner. Thus the old line of disturbance seems to have become a line of weakness in post-Cretaceous times, although the direction of the throw must have been reversed.'[3]

It seemed in favour of this explanation that a fault at Abbotsbury, with a large downthrow south and belonging to the earlier group of disturbances, does actually fall into nearly the required direction. By supposing that this fault ran on about 6 miles westward, nearly along the line of the Ridgeway Fault, but crossed here and there by it, the structure appeared intelligible. On further consideration, however, difficulties arose which I had not at first realized. In the first place, it was necessary to imagine that a post-Cretaceous northerly downthrow was superimposed almost exactly for several miles on the earlier southerly downthrow; next, we had to suppose that this earlier fault had a throw of 2000 feet, and was therefore far larger than any other fault in the Secondary rocks of the South of England. Finally, to account for the Bincombe inlier this great fault had to make four sharp turns, intruding what could only be compared to a pyramid of Oxford Clay and Cornbrash into the Kimmeridge Clay, an almost inconceivable structure. It is, in fact, impossible to devise a combination of normal faults which will account for the position of that inlier without involving great improbabilities.

The alternative explanation is that the faults are of all the same post-Cretaceous age, and that they are overthrusts. Thus the Oxford Clay of Ridgeway has not been faulted against the Wealden

[1] Mr. H. B. Woodward, in a forthcoming Memoir on the Middle and Upper Oolites, points out that the fossils belong to the middle and upper portions of the Oxford Clay, although they occurred in proximity to blocks of Cornbrash.

[2] The shafts seem to have been sunk from the former surface of the ground to the level of the rails, not 50 feet below the rails.

[3] Report on the Easter Excursion, 1889. Proc. Geol. Assoc. vol. xi. p. lii.

Beds, but has been thrust southwards relatively to them; similarly the Forest Marble, Cornbrash, and Oxford Clay of Bincombe have been thrust southwards over Kimmeridge Clay, Portlandian, and Purbeck. The theory involves much speculation, but its difficulties have to be weighed against the still greater objections to the former explanation.

We have to suppose that the Upper Cretaceous rocks rest upon Oxford Clay, Cornbrash, and Forest Marble at no great distance north of the Ridgeway fault. That this is not improbable can be seen by referring to the map of the country between Bridport and Dorchester, where in three localities the Upper Greensand rests on Oxford Clay or some older rock. This results partly from the general dip of the Oolites, but especially is due to the great intra-Cretaceous fault at Abbotsbury. Evidence is not wanting that a similar succession may occur under the Chalk of Ridgeway, for north of the intra-Cretaceous syncline of Upway and Portisham, which introduces a Middle Purbeck outlier, the strata begin to rise sharply northwards, as if to an anticline, before they are cut through by the Ridgeway fault. If the Abbotsbury fault, or any analogous disturbance, continues, it will assist in bringing the Oxford Clay to the required position.

The Ridgeway disturbance was not only contemporaneous with that of the Isle of Purbeck, but so closely resembles it in its effects that we may infer that it also is a thrust, and not a normal fault. The Chalk must therefore have been pushed southwards relatively to the Oolitic rocks, and not faulted down against them, the movement resembling that of the thrust at Ballard Point, where, however, Chalk was thrust over Chalk.

In following the disturbance we have seen that the fracture often follows the base of the Upper Cretaceous rocks, but more frequently runs a little above it. If it anywhere ran below that base, then part of the Oolitic platform on which those rocks rest would be caught up and moved with them. This seems to have taken place at Ridgeway and Bincombe.

For some reason, not improbably connected with the softness and 'greasiness' of the Oxford Clay, the thrust seems to have locally split, the principal plane running in and partly below that formation, while a minor movement took place along or a little above the usual horizon, namely the Upper Cretaceous base. After a separation extending for about $1\frac{1}{2}$ mile, the major thrust-plane rejoined the minor, a wedge of Oolitic rocks thus being enclosed between the two. The effect of the minor thrust was to place Greensand, Lower, Middle, and Upper Chalk in succession on Oolites; and of the major thrust to place Forest Marble, Cornbrash, and Oxford Clay on Wealden, Purbeck, Portland, and Kimmeridge Clay. According to this view, the Portland Stone escarpment west of Bincombe does not end at the village, but should pass under the Cornbrash to join the corresponding outcrop east of the village, a question that might be settled by boring. The structure, viewed on this theory, closely resembles that of known overthrusts in older rocks. Large over-

thrusts of so late a date, however, have not hitherto been recorded in this country.

The Ridgeway fault west of this point becomes a simple fracture, bringing Chalk into contact with Purbeck, Portland, and Kimmeridge Clay in succession. After a course of 13 miles it dies away near Portisham as suddenly as it commenced at Chaldon. It is worthy of notice that along this part of the fault the Oolitic rocks dip southwards, even close up to the fault. If, therefore, they shared in the movement which gave the Chalk a high northerly dip, they must before that movement have had an extremely steep southerly dip, which would bring up the Oxford Clay at no great distance northwards.

(*d*) The Litton Cheney Fault.

This comes into existence abreast of the point where the Ridgeway fault dies out, but about $3\frac{1}{2}$ miles farther north. Like the Chaldon fold, it commences as an arch in the Chalk and Greensand, with the steeper dip in the northern side. This structure, however, can be detected only at the eastern end, for elsewhere the arch has been denuded away, and the disturbance exists only as a fault throwing Chalk and Greensand in succession against Kimmeridge Clay and Corallian rocks. It is worthy of remark that the arch in the Upper Cretaceous rocks nearly coincides with a syncline in Kimmeridge Clay near Long Bredy, but that westward the post-Cretaceous disturbance crosses the earlier syncline obliquely, the direction of the former being about W. 16° S., that of the latter W. 3° S.

The fault differs from those previously described in the fact that the Chalk on its northern side dips southward. There is no evidence here of any overthrusting.

(2) Intra-Cretaceous Disturbances.

These have been distinguished from the later group by the fact that the Upper Cretaceous beds lie undisturbed upon them. They do not occur, or are indistinguishable, in the Isle of Purbeck, but are conspicuous in the Weymouth neighbourhood, and have there caused the great unconformity between the Upper and Lower Cretaceous rocks.

In travelling westwards we first get a hint of this unconformity in the conglomerate and erosion at the base of the Gault near Lulworth, but at the Chalk cliff of Whitenose a magnificent section shows Upper Cretaceous rocks dipping 5° north-eastwards, and resting upon the edges of Purbeck, Portland, and Kimmeridge Clay dipping at 20° to 35° northwards.[1]

[1] The overlap of the Oolitic rocks by the Upper Greensand was first noticed in 1830 by Buckland and De la Beche (Trans. Geol. Soc. ser. 2, vol. iv. pt. i. 1835, p. 10). The section at Whitenose was described and figured by the Rev. O. Fisher in 1854 (Trans. Cambridge Phil. Soc. vol. ix. p. 556).

The Osmington Mills anticline, to which the dip of these earlier rocks is due, runs along the shore west of that place, and is accompanied by a series of smaller rolls that can be seen at low-water in the Corallian rocks farther east. It brings up the Osmington Oolite and overlying Corallian subdivisions in an extremely sharp Λ-shape close to the end of the jetty at the Mills, and gives rise also to some remarkable trough-faulting at that place. The Kimmeridge Clay in the northern limb of this anticline dips northwards at 40°, but the Upper Greensand [1] lies nearly horizontally upon it, the actual junction being fully exposed at Coggin's Barrow. The denudation of the Upper Cretaceous rocks has proceeded just so far as to render possible the mapping of the northern limb of this anticline beneath them; the Portland Stone, for example, repeatedly disappears under the horizontal Upper Cretaceous rocks, always to re-appear in the proper line of strike acquired through the intra-Cretaceous tilt.

Northwards this anticline is succeeded by the Upton syncline, which is no less obviously of the earlier age. There we obtain conclusive proof that the movements were post-Wealden, which indeed might have been inferred from the section at Whitenose. For there they are seen to have been later than the Purbeck rocks, which pass insensibly up into the Wealden.

The Upton syncline is followed by an anticline which has been partly obliterated by the Ridgeway fault, but which can be traced even through the disturbance by observing the difference in dip between the Oolitic and Upper Cretaceous rocks, and thence inferring the dip of the former before they received their second tilt.

The Broadway anticline has hitherto been considered one and the same with the Isle of Wight and Isle of Purbeck fold [2] and has even been assigned to a Quaternary age.[3] In placing it with the earlier disturbances I am guided by its obvious connexion with the Osmington Mills anticline. The Kimmeridge Clay outcrop runs uninterruptedly along the northern sides of both, and both to the east at Osmington and to the west at Abbotsbury is overlain by nearly horizontal Upper Cretaceous strata.

North of the Broadway anticline a syncline brings in the Middle Purbeck strata west of Upway; it can be traced as far as Abbotsbury. On its northern side the strata turn up as though to another anticline, which, however, is hidden by the Ridgeway fault.

At Abbotsbury one of the largest of the earlier faults of the district falls nearly in a line with the Ridgeway fault, of which it has hitherto been considered part. It has, however, a downthrow south of 600 or 700 feet, and passes under the Greensand without displacing it. Were the Upper Cretaceous rocks affected to anything like this extent, they would occur in force under the village.

[1] The Gault is not generally distinguishable from the Upper Greensand in this district.

[2] Hudleston, Proc. Geol. Assoc. vol. vii. (1881) p. 179, and vol. xi. (1889) pp. lii, liii.

[3] Prestwich, Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 43.

Still farther north a number of faults and folds in the Oolitic rocks pass one after the other under the Chalk and Greensand without displacing them in the slightest degree. They run about east and west, and are nearly parallel to the later disturbances, but are occasionally crossed obliquely by them, as at Litton Cheney.

The age of these earlier disturbances can be fixed within narrow limits. That they took place after the deposition of the Wealden and before that of the Gault is proved by the great unconformity between these rocks at Osmington and Chaldon. But their relation to the Lower Greensand can only be inferred. This formation thins gradually westwards in the Isle of Purbeck, and disappears altogether between Mupe Bay and Lulworth Cove. Where last well exposed, in Warbarrow Bay, it seems to pass down into the Wealden Beds, the signs of erosion between the two noticed in the Isle of Wight and elsewhere being unrecognizable. On the other hand, in the same neighbourhood, the base of the Gault becomes increasingly conglomeratic, with marked signs of erosion beneath it, suggesting that the earth-movements, which were so active farther west, were making themselves felt here also. The unconformity at the base of the Gault, moreover, is not a local feature, but has been shown to exist over a large part of England, including, as I am informed by my colleague, Mr. Clement Reid, the Wealden area near Lewes.

At the same time it must be borne in mind that the commencement of the Lower Greensand marked a sweeping change in the physical geography of this part of England, and that this formation also rests unconformably upon Oolitic strata in Wiltshire and the Midlands. It seems possible, therefore, that the movements commenced at the close of the Wealden, but that they were chiefly accomplished at that of the Lower Greensand period.

III. Effects of the Disturbances.

The effects on the physical geography of the region of the two systems of movements described above differ widely. The features due to the earlier disturbances were planed off and smothered under Upper Cretaceous rocks, and have had but little share in the existing configuration. On the other hand, the later disturbances have directly determined the drainage-system, the trend of the scarps, and, indirectly, the form of the coast. It has been shown[1] that in the London and Hampshire Basins the main lines of drainage follow the synclines, while the tributaries flow at right angles to and off the anticlines. Thus the Isle of Wight streams rose in the crest of an anticline and flowed north to join the Frome, which follows a syncline. In the Isle of Purbeck the water-parting held precisely the same relation to the anticline, and the lines of drainage once initiated have been maintained, although denudation has since converted the anticlinal region into a valley, and left standing the

[1] 'Geology of the Isle of Wight,' Mem. Geol. Surv. 2nd ed. 1889, chap. xv.

apparent barrier of Chalk hills between the sources of the streams and their destination.

The Ridgeway axis of upheaval has played the same part in determining the drainage-lines. The crest of the anticline ran close to the line of fault as it now appears at the surface, and northwards from it the streams ran to join the Frome, while south of it they made their way to the English Channel, ignoring the folds in the Oolitic rocks. The Ridgeway line of Downs, from a topographical point of view, compares with the Purbeck or Isle of Wight Chalk-hills. Yet, for the reasons stated, the one is a water-parting, the others are not.

EXPLANATION OF PLATES XVII. & XVIII.

Plate XVII.

Map showing the intra-Cretaceous and post-Cretaceous Disturbances near Weymouth. (Scale: 1 inch=1 mile.)

Plate XVIII.

Sections through and across the Isle of Purbeck Disturbance, and across the Chaldon and Ridgeway Disturbances.

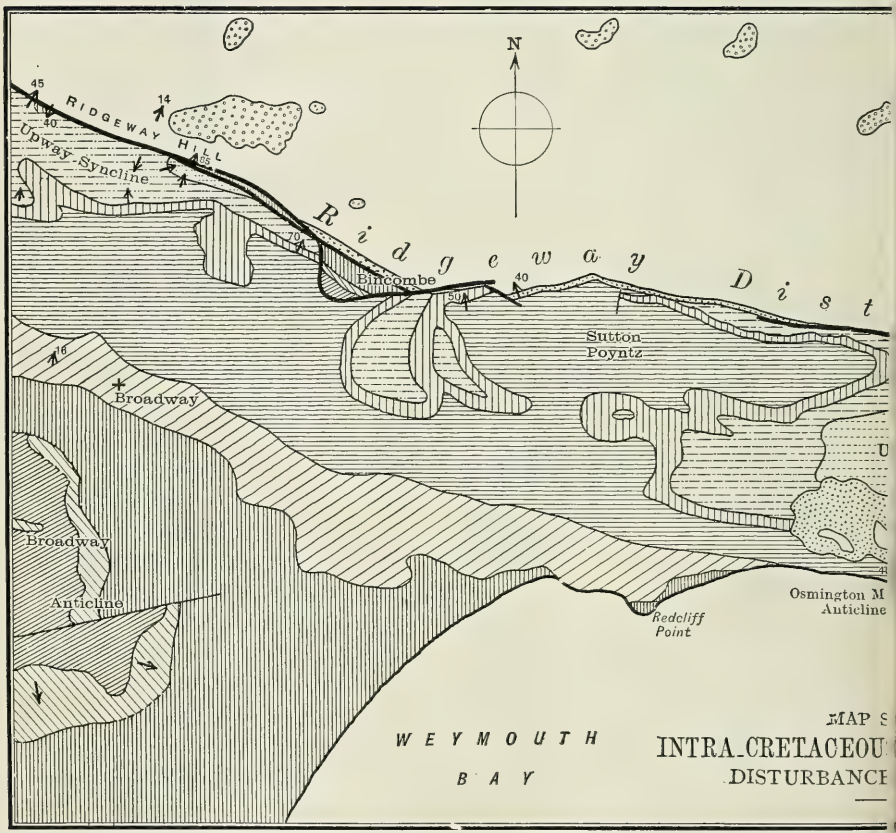
13=Tertiary Beds.
12=Upper Chalk.
(12′=*Belemnitella*-zones.)
11=Middle Chalk.
10=Lower Chalk.
9=Upper Greensand and Gault.
8=Lower Greensand.
(8′=Variegated Sands.)
(8 =Atherfield Clay.)
7=Wealden Beds.
(7′=Wealden Shales.)
(7 =Hastings Beds.)
6=Purbeck.
5=Portlandian.
4=Kimmeridge Clay.
3=Corallian.
2=Oxford Clay.
1=Cornbrash.

Note.—The base of the Upper Cretaceous rocks is shown by a dark line in each section.

Discussion.

The Chairman (Mr. W. H. Hudleston) said that for the second time that evening it had been shown to the Society that much still remained to be done in British geology. The lateness of the hour would preclude anything like an adequate discussion. The determination of the two systems of faulting, one of mid-Tertiary, and the other of pre-Upper Cretaceous age, was of great importance. The disturbance of which the Broadway fault was a member had been held by a distinguished geologist as dating from early Quaternary times, whilst he (the speaker) admitted that he had been disposed to connect it with the one through the Isle of Purbeck. The subject of overthrust was most interesting, but could only be criticized by those whose knowledge of the country was of recent date.

Mr. Clement Reid also spoke, and the Author replied.



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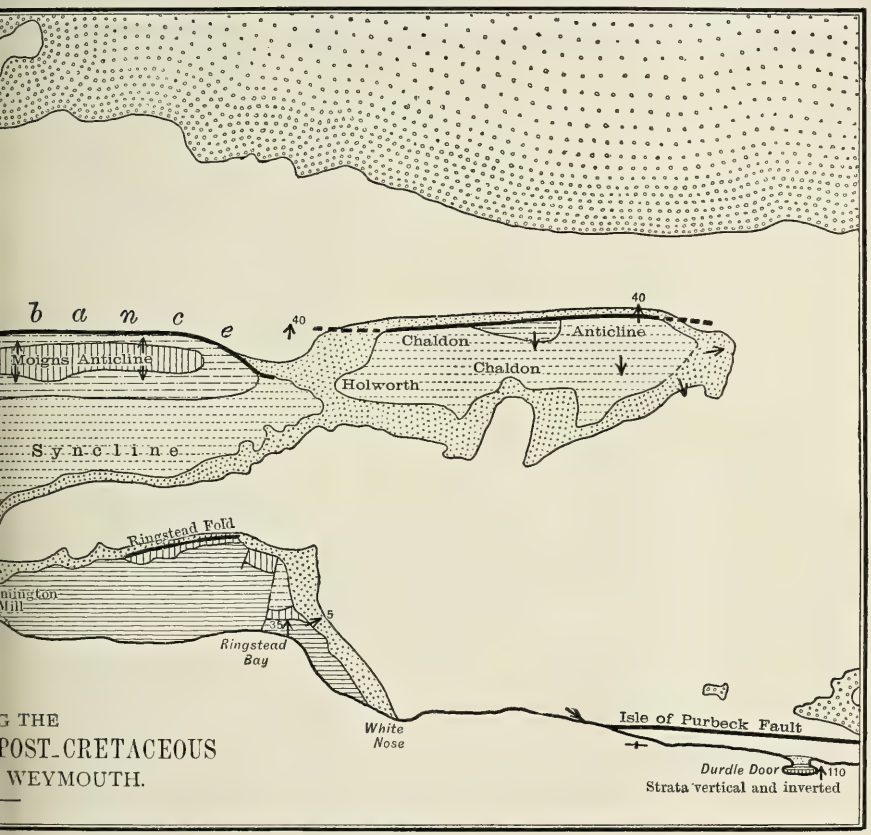

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POST-CRETACEOUS
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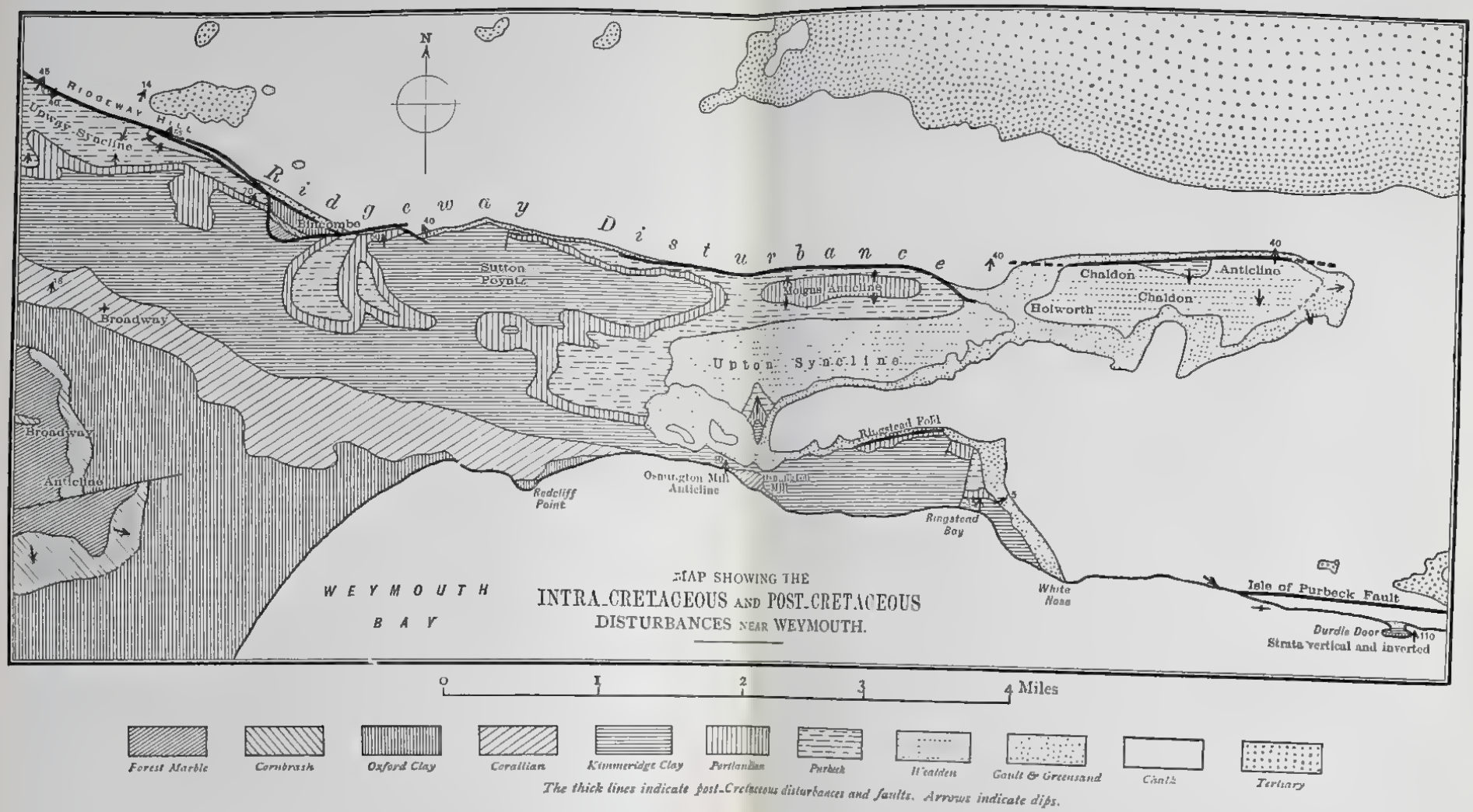
3 4 Miles

Purbeck | Wealden | Gault & Greensand | Chalk | Tertiary

us disturbances and faults. Arrows indicate dips.


N
Ridgeway Hill
Upwey Syncline
Ridgeway Disturbance
Portcombe
Sutton Poyntz
Broadwey
Broadwey
Anticline
Upton Syncline
Holworth
Chaldon
Chaldon
Anticline
Holgns Anticline
Ringstead Fault
Redcliff Point
Osmington Mill Anticline
Ringstead Bay
White Nose
Isle of Purbeck Fault
Durdle Door
Strata vertical and inverted
WEYMOUTH BAY
MAP SHOWING THE
INTRA-CRETACEOUS AND POST-CRETACEOUS
DISTURBANCES NEAR WEYMOUTH.
0 1 2 3 4 Miles
Forest Marble
Cornbrash
Oxford Clay
Corallian
Kimmeridge Clay
Portlandian
Purbeck
Wealden
Gault & Greensand
Chalk
Tertiary
The thick lines indicate post-Cretaceous disturbances and faults. Arrows indicate dips.

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CK AND CHALD
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N 13° W.

13

TURBANCE
Railway.)

N

Tunnel.

Level of Rail

Sea Level

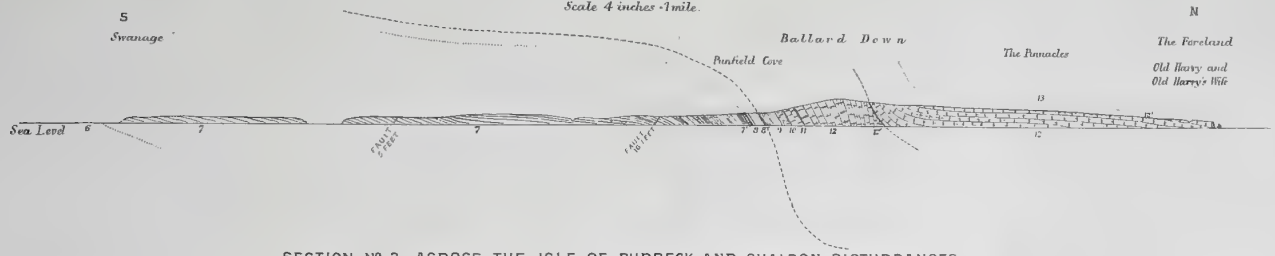
12

9

Mintern Bros. lith.

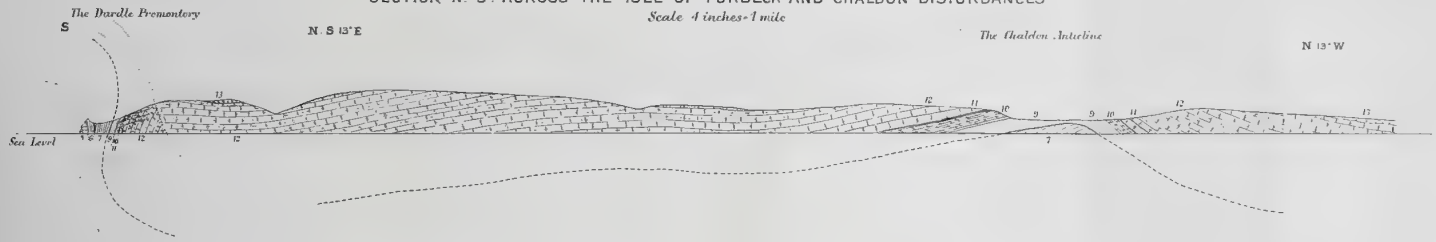
SECTION Nº 1. THROUGH THE ISLE OF PURBECK DISTURBANCE IN SWANAGE BAY AND BALLARD POINT.

Scale 4 inches = 1 mile.



SECTION Nº 3. ACROSS THE ISLE OF PURBECK AND CHALDON DISTURBANCES

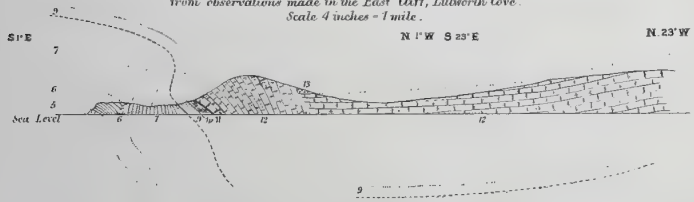
Scale 4 inches = 1 mile



SECTION Nº 2. ACROSS THE ISLE OF PURBECK DISTURBANCE

from observations made in the East Cliff, Ludworth Cove.

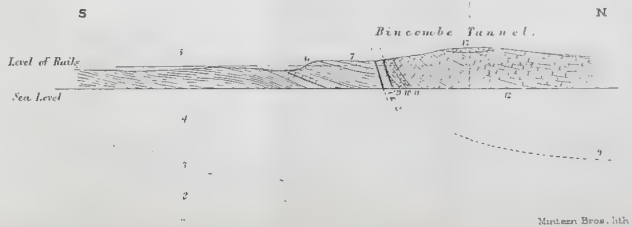
Scale 4 inches = 1 mile.



SECTION Nº 4. ACROSS THE RIDGEWAY DISTURBANCE

(The Section is taken along the Weymouth & Dorchester Railway.)

Scale 4 inches = 1 mile.



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41. *The* Crush-Conglomerates *of the* Isle *of* Man. By G. W. Lamplugh, Esq., F.G.S. With a Petrographical Appendix by W. W. Watts, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey. Read June 19th, 1895.)

[Plate XIX.—Map.]

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I. Introduction.

Among the Skiddaw Slates of the Isle of Man there occur in some localities considerable thicknesses of a curious conglomeratic rock which it is my object to describe and discuss in the following communication.

In spite of the extended development of this rock it has hitherto received scant attention, the only noteworthy reference to it that I have found in previous geological literature being the passing mention by Henslow, as follows:—'Near Ballaneah[1] I observed the cliffs to consist of angular fragments of clay-slate embedded in a clay-slate paste, and what is curious, these fragments are scarcely to be distinguished from the base, excepting on the surface of the rock which has been exposed to the action of the waves, where they become sufficiently apparent by the fragments assuming different tinges of colour, giving the specimen a mottled appearance.'[2]

In dealing with this matter I should have preferred to avoid for the present the broader question of the general arrangement of the Skiddaw Slates in the Island, but from the nature of the subject this will not be altogether possible.

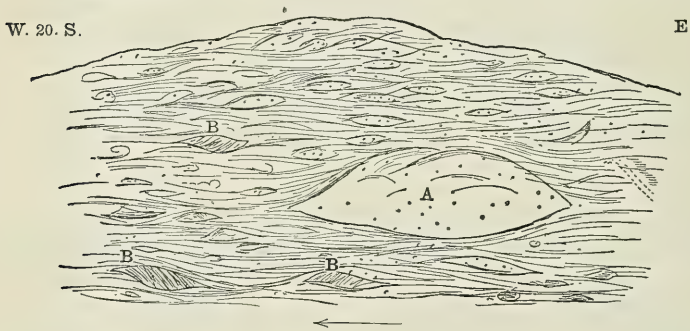
[1] Evidently 'Ballanayre' of the Ordnance Maps.
[2] Trans. Geol. Soc. ser. 1, vol. v. (1820) p. 490.

II. General Description of the Crush-Conglomerates.

Although the conglomeratic rocks to be described vary considerably in different exposures, and even in different portions of the same exposure, there are yet certain characteristics which are common to the whole of them. Essentially, these crush-conglomerates are rocks made up of scattered fragments set in a slaty matrix.

The fragments vary in composition, but most frequently are composed of fine-grained grit or sandstone, and of sandy slate; with less abundant pieces of coarsish grit, of banded flaggy slate, and of purely argillaceous smooth blue slate or shale. These fragments are usually phacoidal or lenticular in outline,[1] but the shape differs in different sections, and also according to the size. In some localities many of the smaller inclusions are quite rounded, while in others they take the form of subangular or spindle-shaped strips (see figs. 7 and 8, p. 572). The fragments are of all sizes, from blocks several feet in diameter (see fig. 1) to particles of microscopic

Fig. 1.—*Crag at the southern edge of Cronk Sumark, Sulby. (Showing large block of coarsish-grained grit in crush-conglomerate.)*



A. Block of sheared, slightly felspathic grit, about 8 feet long, embedded with many fragments of fine-grained flagstone and hard clay-slate in a matrix of bluish slaty material.

B. Inclusions in which the original bedding is still visible.

The arrow indicates the probable direction of the shearing.

dimensions. They are, as a rule, indiscriminately mingled, large and small, in a highly-sheared slaty matrix; but the average size of the inclusions varies greatly in different localities, and there is sometimes a total absence of the larger fragments.

A glossy sericitic face, evidently the result of shearing, coats the harder inclusions; and planes of similar character are abundant throughout the matrix, and sometimes cut the fragments. These schistose planes determine the weathering and the fracture of the

[1] Such fragments often appear nearly circular when cut across at right angles to their longer axis.

rock; and when, as frequently happens, they lie very close together and the inclusions are all of small size, the fragmental character of the mass is not at all evident in ordinary exposures, and only appears when a fresh cross-fracture has been made in it. There is usually an abundant development of iron pyrites in the rock, sometimes finely disseminated, and sometimes, as at Cronk Sumark, in cubical crystals from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter showing very marked signs of crushing and shearing.

To the unaided eye the rock presents no especial evidence of mineral metamorphism, either in the slaty matrix or in the separate fragments, the neighbouring unbroken rocks frequently exhibiting greater alteration in this respect. Its appearance under the microscope is described in Mr. Watts's Appendix to this paper.

Such is the composition of the rock over large areas; and where the modifications which reveal its true origin are absent, it might readily be mistaken for a highly-sheared rock of originally fragmental character, though a lithological examination of the included fragments would show at once that it was not a true tuff, while the slaty nature of the matrix would render difficult its explanation as a water-borne conglomerate. If we were to imagine an ancient boulder-clay, made up of Skiddaw-Slate material and thoroughly consolidated and much altered by shearing, we should have a rock very similar to this in appearance. But that it is essentially a 'crush-conglomerate,' due to the breaking-up under pressure of alternations of flaggy slate and thin grit-bands, becomes abundantly evident wherever a wide exposure is studied.

III. The 'Skiddaw Slates' of the Isle of Man.

Since very little detailed information regarding the Skiddaw Slates of the Isle of Man has yet been published, it becomes necessary before dealing further with the crush-conglomerates to give an outline of the leading features of these rocks.

The Skiddaw Slates, occupying 200 square miles or four-fifths of the whole Island, consist of a mass of sedimentary strata of unknown thickness, ranging lithologically, by alternations, from coarse-grained grits, through sandy flags, to fine argillaceous shaly slates. They are much cut and interpenetrated by igneous intrusions; but in spite of some statements to the contrary,[1] no positive proof of contemporaneous volcanic activity has yet been forthcoming. No base to the series is known, and where its superior surface comes in contact with the overlying Carboniferous rocks a very pronounced unconformability is presented. With the exception of *Palæochorda* and other obscure worm-markings, which are rather plentiful in the sandy beds, the only fossils as yet known are the *Dictyonema* and the imperfect cast of a trilobite recorded by Mr. Bolton,[2] and these are insufficient to settle the age of the rocks, which may be Lower

[1] Harkness and Nicholson, Quart. Journ. Geol. Soc. vol. xxii. (1866) p. 488; H. Bolton, Rep. Brit. Assoc. (Nottingham) 1893, p. 770.

[2] *Op. supra cit.* and Geol. Mag. 1893, p. 29.

Silurian or older. Their correlation with the Skiddaw Slates of the Lake District seems to rest on a satisfactory basis; but as the Skiddaw Slates of that region are believed to cover a wide range in time,[1] and as our knowledge of their stratigraphy is still very limited, this correlation is of uncertain value.

Although most observers of the Manx Skiddaw rocks have remarked on the contorted character of the bedding, it is evident that the resultant complexity of the structure has not been realized, and that the strata have been credited with a greater simplicity of arrangement than they possess. Because the beds on the western side of the Island from the coast up to the central hilly axis have usually a northerly or north-westerly dip, while on the eastern side the prevalent dip is to the opposite direction, it has been assumed that the structure is that of a simple anticline. But this interpretation is almost certainly erroneous; and instead of the rocks of the coast-line having risen, before denudation, as an arch over the central area, it is more probable that the contorted grits and flags so largely developed at the lower levels on both sides of the Island pass, as a highly folded platform, beneath the argillaceous mass out of which most of the central hills are carved.

Pending the completion of the detailed examination of the whole Island it would be premature to lay too much stress upon this reading of its structure; but so far as my work has yet gone the supposition agrees best with the observed facts, in spite of some apparent reversals of the general order by which the grits are locally brought uppermost.

IV. The Distribution of the Crush-Conglomerates.

(1) Summary of the Field-evidence.

For the convenience of the reader who may not require to enter into the local details, I will give a brief summary of the field-evidence before entering into the more circumstantial account of the sections.

As a result of the intense shearing which the Skiddaw Slates of the Isle of Man have everywhere undergone, actual disruption of the bedding has in certain localities taken place on a very extensive scale. The crush-conglomerate thus formed attains its widest development on the north-western side of the central axis of the Island, north of the valley which cuts the hill-range between Peel and Douglas, though it is also seen, on a limited scale, in a few localities farther south. It is well exposed in the cliffs 3 miles north of Peel; but the finest sections are in the interior, in Sulby Glen, where the structure has a thickness of some hundreds of feet, and runs continuously north-north-east for 5 miles, with a probable extension southward for 3 miles farther. It is usually flanked on the one side by gritty flags and on the other by dark clay-slate.

[1] J. E. Marr, Geol. Mag. 1894, p. 122.

It is affected by an imperfect cleavage ('shear-cleavage')[1] later than the brecciation. Several igneous dykes which intersect it are affected by the same cleavage, though not by the earlier crushing.

From the mouth of Sulby Glen the crush-conglomerate extends eastward for 4 miles farther, to Ramsey, at first in outcrops having a horizontal breadth of over a mile, but afterwards in a series of comparatively narrow subparallel bands; and it is suggested that these exposures represent the emergence of a deformed plane. At Ramsey its farther course is cut off by the intervention of a bank of drift, just before it reaches the east coast. In many localities the sections show clearly every stage in the formation of the crush-conglomerate.

(2) Detailed Account of the Sections.

The more closely the Skiddaw Slates of the Island are examined, the more evident does it become that they have everywhere suffered deformation and shear. Strata in which the bedding-planes appear at a first glance to be quite regular will be found on nearer examination to have their thinner layers pinched or puckered out so frequently, that any particular lamina can rarely be traced for more than a few feet or yards. Sometimes, where the beds have been stretched, the laminæ disappear against each other obliquely as in faint cross-bedding; and again, where packing has taken place, the lines of stratification are confused in a series of wrinkles, which emerge on the bedding-planes as small parallel folds closely resembling ripple-marks (see figs. 3 & 4, pp. 570, 571). In the finer-grained flaggy beds the surfaces are sometimes tesselated by narrow regular pleats in parallel sets crossing each other obliquely, somewhat resembling 'sun-cracks' in aspect; and in the more homogeneous argillaceous deposits the whole mass is frequently striated throughout with shear-cleavage, sometimes in two different directions, to the more or less complete obliteration of the original bedding. In general terms, these structures may be summed up as indicating acute folding, accompanied or followed by a shearing fluxion-movement usually along the planes of bedding, with the later development of obscure cleavages obliquely across the folds.

Many of the igneous intrusions also, especially the narrower dykes, have been so greatly sheared that their crystalline constituents have been disintegrated. Sometimes, indeed, the dyke has become quite schistose, and its margin frayed out into the enclosing slates.

These indications are, on the whole, most acute on the north-

[1] Throughout this paper I have, perhaps somewhat arbitrarily, used the term 'shear-cleavage' to denote the imperfect cleavage (to some extent a 'strain-slip cleavage') which usually affects the rock as a mass and determines its fracture; and have confined the term 'strain-slip' to the wider-placed and better-defined planes of slipping or 'close-joints-faulting' which are more intimately connected with the brecciation-movements. As will presently be shown, the 'shear-cleavage' is of later date than the brecciation, while the 'strain-slip' planes are at least as old as that movement.

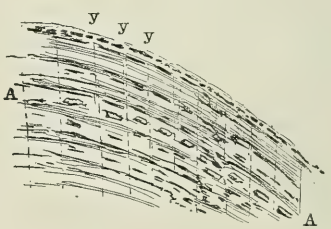
western side of the central axis, where the prevalent dip lies between west and north. On the south-eastern side the rocks are indeed intensely folded, but the limbs of the folds are usually longer and straighter, and there is less puckering; so that, as a rule, it is only in the coast-sections and in the deeper quarries that the folding becomes evident; while on the other side there is presented from end to end of the Island a shorter and more intricate system of folding, and a constant tendency of the shear-strain to produce an actual brecciation of the bedding, especially in the vicinity of masses of grit. This tendency increases very markedly from south-west to north-east, being found only on a local and limited scale south of the central valley which crosses the Island between Douglas and Peel, but to the north of this valley rapidly becoming an important element in the stratigraphy.

(a) *Coast Sections.*—The most southerly occurrence of the crush-structure known to me occurs in the cliffs on the western side of Fleshwick Bay (see map, Pl. XIX.). Here at high-water mark and in the crags above, a much-folded series of sandy slates with occasional layers of grit becomes locally dispersed into a mass of detached fragments of grit included in a sheared slaty matrix.

Three miles north of Fleshwick the brecciation is again met with, on the foreshore under Gob Breac beyond Cronk ny Arrey Lhaa, but the separated fragments are small in size, and the structure not very notable.

At the rugged reef of the Niarbyl,[1] one mile farther north, we reach the southern margin of a series of thin-bedded slaty flags and fine-grained grits, slightly calcareous in places, which extends thence without interruption for 5 miles, until it disappears by faulting against the newer rocks (Red Sandstone and Conglomerate) at Peel (see map, Pl. XIX.). These flags are throughout magnificently plicated, and show almost everywhere the strain-slip cleavage and other shear-structures in great perfection and variety, with such local discontinuity of the bedding by stretching as shown in fig. 2, or by close inpacking as in fig. 3 (p. 570), but otherwise they have preserved their original stratification-planes. Such strata as these would, I think, if rent

Fig. 2.—*Crest of fold in cliff at northern side of The Ladder, Contrary Head, Peel.* (*Length about 4 feet.*)



A-A. Pale band in flaggy sandy slates, pulled apart into pebble-like lenticles, 1 to 2 inches in length.
y, y, y. Faintly-indicated planes of strain-slip.

[1] Pronounced Nĕ-ār-b'l.

into fragments yield a crush-conglomerate very like that in Sulby Glen presently to be described. These rocks I propose to term the 'Niarbyl Flags.'

They re-appear for a short distance in the coast-section $2\frac{1}{2}$ miles north of Peel. Immediately beyond the northern termination of these flags in the coast-section a huge mass of slaty conglomerate makes its appearance, occupying the whole of the foreshore and the cliff 40 to 50 feet high in the headland south of Gob y Deigan, 3 miles north of Peel. It is here that the structure was noticed by Henslow.[1] The section is however rather difficult of access; and for convenient study the inland exposures of Sulby Glen and of the neighbourhood of Ramsey are preferable.

About a mile farther north, at Gob ny Creggan Glassey, there is again an exhibition of the brecciated structure, but it is confined to a narrow band of limited extent. From a little beyond this place, the cliffs of the west coast are composed entirely of drift.

(b) *Inland Sections.*[2]—The character of the inland exposures is frequently so unfavourable for study that, as Henslow pointed out, the conglomeratic structure is not always easy to discriminate, especially where the breccia is fine-grained, and the inclusions chiefly argillaceous. It is therefore possible that the structure may exist in a few places where I have as yet failed to detect it; but such cases are not likely to be numerous or extensive.

In passing inland from the coast in the neighbourhood of Gob y Deigan a belt of about $\frac{1}{2}$ mile of contorted flaggy slates and grits is traversed, and on the farther side, around the head of Glion Cam and in the quarterland of Corvalley and again near Chester, some obscure exposures of the crush-conglomerate may be seen. On the same line of strike about 2 miles farther north-east similar traces occur, on the slope above the village of Kirk Michael, but no clear section is afforded in any of these localities. It is not probable, however, that the crush-material of this belt is anywhere thick.

For more satisfactory exposures we must pass 4 miles farther inland, across the hilly ridge which rises in Slieau Freoaghane to a height of 1602 feet. This ridge is composed of a variable series of banded and on the whole rather sandy beds, with broad masses of dark blue, more purely argillaceous slates. From it we descend into the wide elevated basin of the Sulby River, wherein occurs by far the grandest development of the crush-conglomerate to be found in the Island, and fortunately under circumstances peculiarly favourable for examination.

(c) *Sulby Glen.*—A feeder of the River Neb which takes its rise on the col between Lhargee Ruy and Colden, flows near its head for about 100 yards over a slaty breccia, crowded with subangular and lenticular fragments of fine-grained grit and pale slate, of which the largest are about 6 inches in length. A mantle of

[1] Trans. Geol. Soc. ser. 1, vol. v. (1820) p. 490.

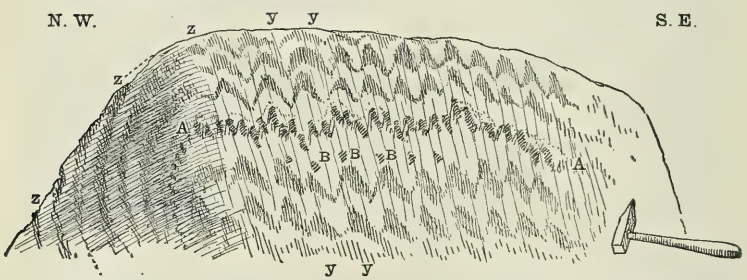
[2] Fuller local details of these sections are reserved for the Survey Memoir.

drift covers the surrounding hill-slopes, so that the prolongation of the structure from this point cannot be directly traced; but the exposure lies exactly in the line of strike of the similar material found in Sulby Glen; and as there is also other evidence to connect them, I regard this as the southern extension of the Sulby Glen zone.

The first good section, however, in the Sulby basin itself lies about 3 miles farther north-north-east. Here in the bed of a rivulet draining into the Druidale branch of the main stream, west of the ruined farmstead of Close, there is an outcrop 150 yards in breadth; from this, by reason of the flaggy fracture of the rock along the later shear-planes, excellent specimens of the crush-conglomerate may be obtained.

Northward from this point the exposures are practically continuous, and in the craggy walls of the rapidly deepening valleys the material may be studied in every stage of its formation, and the expanding zone traced almost without interruption down to the mouth of the Glen, 5 miles distant.

Fig. 3.—*Sketch-section of strongly-banded sandy slate in eastern bank of Sulby River, below Snaefell, 450 yards N. of 'Lead-mine.'* (*Length=about 5 feet.*)



A A. Band of grit about ½ inch thick among puckered slates, crumpled and partially broken.

B B B. Isolated pebble-like fragments of grit, presumably detached or squeezed out from the band A.

y–y y–y. Planes of strain-slip or close-faulting.

z–z–z. Planes of the later shear-cleavage, striking N. 40° W. with the bedding, but crossing the folds with a dip of about 30°.

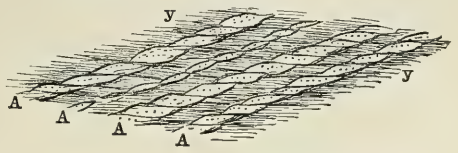
Five hundred yards below Close the conglomerate strikes into the main stream; and though here, as in a few other places in the Glen, somewhat confused by later faulting, and by the presence of large blocks of the unbroken strata in its midst, its general north-north-easterly trend remains unaltered.

Where Glen Crammag joins the main valley the conglomerate forms the high craggy slope on the southern side of the river, and extends backward for 300 yards up the bed of the feeder.

Under the Druidale farmstead, ¼ mile farther north, the brecciated zone is fully 500 yards in breadth, but includes some portions in which the bedding-planes are only partially broken up.

In this locality many interesting variations of the structure may be studied. Thus, in the craggy elbow on the western bank under the farmstead of Croit, the gritty inclusions, admirably displayed by weathering, are widely scattered, usually of small size—not often exceeding 2 inches in diameter, and frequently rounded as if by actual rotation; and the whole mass is crossed by well-defined 'shear-cleavage,' oblique to the lie of the 'pebbles.' This cleavage, which must, I think, be a structure of

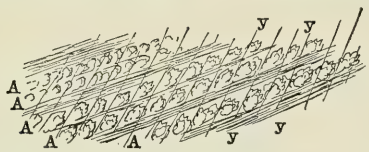
Fig. 4.—*Part of crag on western side of Sulby Glen, west of B. M.* 137′ 6″. (*Length = about 2 feet.*)



A A A. Bands of grit 1 to 3 inches thick, in sheared slates; cut, displaced, and lengthened by oblique strain-slip *y–y*.

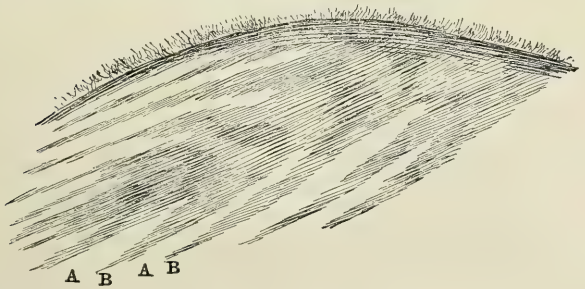
The surface of the bands shows pseudo-ripple-marking.

Fig. 5.—*Part of crag in Glen Dhoo, Ballaugh, on hillside S.E. from Glen Dhoo Farm.* (*Length = about 2 feet.*)



A A A. Broken grit-bands in sheared slates, cut by strain-slip (*y–y*) and the segments slightly rolled.

Fig. 6.—*Part of crag in Glen Dhoo, Ballaugh, western slope, above 'T. Mill.'* (*Length = about 3 feet.*)



Sandy (A A) and slaty (B B) bands frayed out and obliterated in the crest of a fold by shear-cleavage.

The shaly matrix of the crush-conglomerate has probably been similarly produced.

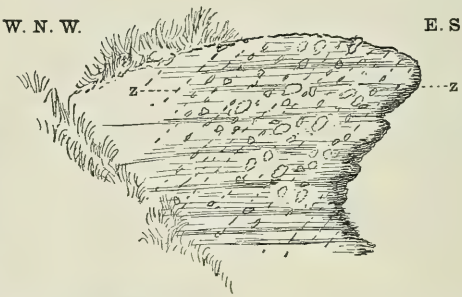
Note.—The localities indicated in figs. 2, 5, and 6 are not in the immediate vicinity of the crush-conglomerate. These sketches were selected from those contained in my notebook as convenient illustrations of the points dealt with. Parallel cases could in every instance be found in the rocks bordering on the crush-zones.

later date, produced separately from and independently of the brecciation-movement, sometimes cuts and sometimes avoids the grit-fragments (see figs. 7 & 8). (See also Mr. Watts's Appendix, p. 594, & Pl. XX. fig. 5.)

In the bed of the main stream, only a few yards distant, the inclusions are much larger in size; among them are some fragments of coarse-grained grit; and they are mostly quite lenticular and often preserve in their interior traces of their proper bedding.

Fig. 7.—*Crag on northern slope above Druidale stream, at junction with Sulby River.*

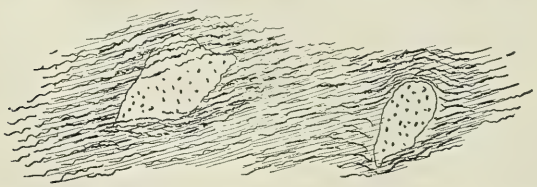
(*Length = about 3 feet.*)



The crush-conglomerate has a shear-cleavage *z–z* obliquely crossing the long axes of the grit-fragments. The section is along the strike of the shear-cleavage, which dips N. 20° E. at 35°. The broader faces of the grit-fragments are dipping to N.W. Their maximum diameter, in this section, is 2 inches.

In the crags a dyke of igneous rock of the 'greenstone' or diabasic character is seen among the conglomerate. This must have been injected after the brecciation of the slates, since it is itself unbroken and moreover slightly alters the conglomerate surrounding it. Yet it has undergone pressure sufficient to develop an obscure cleavage, probably equivalent to the later shear-cleavage just described; and of an originally porphyritic constituent there remain now only

Fig. 8.—*Part of crag on northern slope above Druidale stream, near junction with Sulby River.* (*About $\frac{1}{2}$ nat. size.*)



Crush-conglomerate, with the later shear-cleavage planes in the shaly ground-mass partly swerving around, and partly crossing, included fragments of fine-grained grit.

smeared blotches of greenish chloritic material. These facts seem to require a definite interval for the injection of the dyke, after the brecciation-movement and before the development of the 'shear-cleavage.' I suspect that it is a continuation of this dyke which

is seen in the high crags of the western side of the main valley $1\frac{1}{2}$ mile farther north, where the rock is quarried for road-mending; and again on the opposite side lower down, still traversing the conglomerate, but there passing out also into the unbroken strata (see section, fig. 9, p. 574).

North of Druidale for a space the sections are not so clear, but the brecciated zone may be traced crossing the stream at the Tholt-e-Will bend and ascending the steep valley-wall on the northern side, above the schoolhouse.

From this point there appears to be an increasing tendency in the structure to split into slightly divergent, though on the whole parallel, bands, with expanding wedges of highly contorted, but yet unbroken, slates between them. Of several possible reasons for this arrangement, I am inclined, after consideration of the whole of the evidence, to adopt the view that it is due in this area to the later folding of an original plane. Many of the facts might, perhaps, be as well explained by overthrust—or even by normal faulting, or by the concurrent formation of the conglomeratic structure in the equivalent limbs of a parallel series of folds. But the wide horizontal spread of the material on the high land between Sulby Glen and Ramsey (see map, Pl. XIX.) seems to indicate the existence in this region of a definite brecciated plane; and with the abundant evidence that earth-movements continued long after the making of the conglomerate, the distortion of any plane formed at that early stage appears almost inevitable.

From the crest of the ridge just above the Tholt-e-Will schoolhouse we may trace the main branch of the conglomerate, through the broken ground around Craigmooar, to its junction with the Sulby valley again on the northern side of the bend. Gritty flags, well seen under Sharragh Bedn, lie, as usual, to the west of it; while on the east there is a crumpled mass of dark argillaceous material with an imperfect cleavage, which forms the left wall of the Sulby valley in the elbow and has been extensively quarried on the opposite bank at Ballaskella.

East of this mass of slate another band of the crush-material is, however, met with in the beds of the streamlets which descend into Sulby Glen from the east. The sections are insufficient to show the relation of this to the main band, but I think it may be regarded as the partial emergence of the crest of a fold, though in that case the plication of the plane must be rather acute.

North of Ballaskella the main band is almost continuously exposed in the precipitous and somewhat inaccessible crags of the western side of the valley. Its base at first forms only the crest of the wall; but under Killabraggah this descends rather sharply to the level of the river, and the upper limit of the conglomerate is then found to fall just below the top of the slope, giving a vertical depth at this point of between 250 and 350 feet. If the zone be steeply inclined, however, its true thickness may fall short of this. Farther north, as we shall see, both its extent and thickness are considerably greater.

The trend of the river below this point carries it again gradually

Fig. 9.—*Section across the zone of crush-conglomerate on the eastern side of Sulby Glen.*
(*Scale, horizontal and vertical: 6 inches = 1 mile.*)

The section is drawn to include all the crags seen on the hillside, which slopes at about 40°.

across the strike of the conglomerate, which now appears in the eastern slopes and finally abandons the western side altogether at the Glen Mooar bend. It is here very well exposed for about 250 yards in the deep trough cut by a tributary stream which comes in from the east. This stream has no name on the Ordnance map, but the cascade by which it reaches the main glen is known to the country-folk as 'The Cluggid' (=throat). East of the conglomeratic belt this gully and its craggy walls are composed, for the next $\frac{3}{4}$ mile, of compact dark slate with imperfect cleavage and faint traces of contorted bedding, after which for a few yards the crush-material is again revealed, and beyond this some flaggy grits are encountered. This arrangement is very suggestive of the acute folding of the brecciation-plane.

The crags lying in the fork between Sulby Glen and the Cluggid exhibit a continuous section across the strike of the brecciated zone, as shown in the accompanying illustration (fig. 9), and I know of no place where the character of the structure and its relation to the surrounding strata can be so satisfactorily studied. Every stage in the breaking-up of the highly-contorted grits and banded sandy slates which form the northern part of the exposure can be distinctly traced, and in places amid the mass of the breccia there are isolated patches of still coherent beds from a few feet to a few yards in diameter. Occasionally in these crags, as also in sections elsewhere, there may be seen a distinct U- or V-shaped arrangement of the grit-frag-

ments (see fig. 10), which I take to be an indication of sharp folding of the crush-material. I noticed also a few instances wherein a well-defined inclusion was itself composed of breccia, of a texture and tint different from that of its matrix, as though portions of a mass already reduced to the state of crush-conglomerate had been again broken up. At the north-western margin of the zone, where the contorted flags begin to resume their continuity, there are some narrow strips of the disrupted rock interbedded with comparatively unbroken bands, as though the brecciation had commenced and spread more readily along certain selected beds. The later shear-cleavage is also strongly developed in the section. (See Mr. Watts's Appendix, p. 591, & Pl. XX. figs. 1–4.)

Fig. 10.—*Part of a crag in Sulby Glen* (100 *yards north of* '*Limekiln*,' *Glen Mooar*, 6-*inch map*).

(*Length*=*about* 3 *feet.*)

This section shows fragments in crush-conglomerate, with linear arrangement suggestive of a broken overfold. The larger inclusions are of pale-greyish flagstone or fine grit, 1 to 3 inches in diameter. The slaty ground-mass is crowded with smaller fragments.

The igneous dyke which cuts the crush-conglomerate at this place has already been referred to. It is well exposed in the lower crags above the junction of the streams, and may be followed thence continuously for about 150 yards, where it passes from the crush-material to the unbroken slates, among which it may be obscurely seen at intervals for 300 yards farther. It is from 10 to 20 feet thick. (See Mr. Watts's Appendix, p. 596.)

The width of outcrop of the crush-conglomerate in these crags, measured across the strike, is slightly over 400 yards, and its vertical depth exceeds 500 feet, the top being lost in the grassy ground beyond the valley-slope.

The fine ranges of crags on the opposite side of the valley which descend from the summit of Mount Karrin (1084 feet) are composed of contorted flaggy grits with slaty partings, and are evidently continuous with those which flank the crush-conglomerate. They exhibit many beautiful shear-structures not far removed from actual brecciation, among which are many fine examples of the parallel plication and partial fracture of the bedding which so closely simulate ripple-marking on the surfaces of the more flaggy layers (see fig. 4, p. 571). It is probable that many of the so-called ripple-

marked surfaces recorded among the older rocks will eventually be found to be of this nature.

(d) *Sections east of Sulby Glen.*—For the exposures between Sulby Glen and the east coast a briefer description will serve. They are essentially similar in character to those already described, but at a few points important features not hitherto encountered will require consideration.

The section at Cronk Sumark,[1] or Primrose Hill, the crag rising steeply above the drift in the expanded mouth of Sulby Glen, is especially noteworthy.

Thick-bedded, rather coarse-grained, contorted grits are slightly exposed near the foot of this hill on the north-western side, while 40 or 50 feet higher on the opposite face a large quarry has been excavated in a welded mass of obscurely-cleaved dark blue slate in which some traces of folded bedding can in places be made out. From the talus of this quarry Mr. H. Bolton has recorded the fossil identified as *Dictyonema sociale*, referred to on a previous page (565).[2]

At the southern edge of this quarry the brecciated structure sets in, and extends thence eastward over the remainder of the hill, being well exposed in the crags (as shown in fig. 1, p. 564), and in the quarry behind the farmyard at Grangee, where large cubical crystals of pyrites are very abundant. On the supposition of the deformation of the brecciated plane, this exposure could be regarded as lying on the north-western side of an anticline striking across into Sulby Glen.

From Cronk Sumark the crush-material may be traced eastward for $\frac{1}{2}$ mile, into the cliff-like slopes of Kerroo Mooar overlooking the northern plain, where it is intruded upon and altered by an igneous rock (altered diorite or dolerite; see Mr. Watts's Appendix, p. 596) different in character from the Sulby Glen dyke.

In Narradale, the most easterly of three small glens which flow nearly parallel with the Sulby River, and after uniting join that stream near Cronk Sumark, there is a very wide exposure of the crush-conglomerate, extending from the ravine at Grangee southward for rather over a mile, broken only by occasionally narrow intercalations of bedded slate and by several 'greenstone'-dykes.

In the right bank of the stream, south-west of the only farmstead in the upper part of the glen, there occurs a large, partially-rounded, boulder-like mass of coarsish grit or quartzite, measuring not less than $14 \times 8 \times 6$ feet, apparently embedded in the conglomerate, and it is the largest rounded block that I have yet seen in this position. Its surface is, as usual, coated with a smooth, highly-sheared sericitic layer, to which little flakes of the breccia

[1] The name should probably be Cronk Shimmirk=the Hill of Refuge. There are traces of an old fortification on the summit. Being within $\frac{1}{2}$ mile of the Sulby Bridge Railway Station, this hill is a very accessible locality for the study of the crush-conglomerate.

[2] Rep. Brit. Assoc. (Nottingham) 1893, p. 771. The fossil is evidently extremely rare, and my own repeated search has as yet been quite unsuccessful.

adhere in places; but within this crust the rock, as petrological examination has shown, is practically unsheared (see Mr. Watts's Appendix, p. 594).

The southerly portion of these Narradale exposures lies well within the line of strike of the main conglomerate-zone of Sulby Glen, and in the intervening ground, about a mile in width, there is sufficient evidence to indicate the direct continuation of the structure in this neighbourhood. Farther to the north-west, however, there is certainly an area of sandy slates with unbroken or very slightly broken bedding, which possibly represents the beds below the plane of brecciation in the crest of the supposed anticline. The anticline appears to 'nose out' before reaching Narradale, and that stream probably flows almost wholly along the conglomerate-belt. But neither here nor elsewhere is the evidence sufficiently clear to justify absolutely positive statement as to the disposition of the crush-material as a whole.

Between Narradale and Glentramman the conglomerate extends over the high grassy plateau in a band nearly as wide as the stream-section just described, while the unbroken gritty flags and banded slates occupy the slopes overlooking the plain. But in Glentramman and eastward from this point to the coast there is no such widespread continuous development of the structure; and the exposures arrange themselves as a series of disconnected subparallel strips or lenticles fading out rapidly at both ends. While this arrangement is quite in keeping with the theory of a contorted plane, it is also not opposed to the alternative view that the structure may have been developed in originally limited and isolated patches along the limbs of a series of folds.

A peculiarity in the arrangement of both the broken and unbroken rocks may here be mentioned. It is that the orientation of the rock-masses as brought out by the mapping is not quite normal to the general dip, but approaches by several degrees more nearly to a north-and-south course than the inclination of the bedding-planes would indicate. The general strike thus makes an angle with the general dip acute to the northward where the dips are directed between north and west points, and to the southward on the opposite side of the main axis of the Island. This angle, moreover, is usually more acute for the gritty rocks than for the argillaceous masses. Of course the dips in beds so folded give no clue to the true sequence of the strata, but I take it that they do usually indicate the axis of the folds; and the divergence of the general strike from this axis seems to show that the rocks since the primary folding have been affected on a broad scale by earth-movements acting along new lines.[1]

In accordance with this arrangement, the general dip of the contorted slates and flags in the upper part of the Sulby basin being usually somewhat to the westward of north-west, the course of

[1] This is probably a point of prime importance in the stratigraphy of the Island; I am paying especial attention to all the evidence bearing upon it, and hope to be able hereafter to deal more fully with the question.

the rock-masses, including the crush-conglomerates, is about north-north-east. But in passing down the Glen the general dip swerves to the northward of north-west; and between Sulby and Ramsey is generally N. 10° to 20° W. This alteration has at first very little effect upon the zone of brecciation, which continues to strike N.N.E. until it leaves the Sulby valley. But farther eastward, its trend swerves to about the same extent as the dip, the conglomerate-bands, so far as can be made out, striking nearly S.W. and N.E., and thus still preserving the obliquity of their relationship to the general dip.

The arrangement of the crush-material in parallel bands is nowhere better seen than on Skyhill, the bold ridge between Glentramman and Glen Auldyn. The weathered crags on the northern crest of this hill show very clearly the gradual disruption of the grit-bands; while farther south three, or possibly four, separate zones of the crush-structure, each narrower than the last, may with some difficulty be traced, with wedges of more or less unbroken strata between them. The north-eastern prolongation of the two most northerly of these bands is lost in the low ground, but those south of the Skyhill farmstead probably cross to the eastern side of Glen Auldyn and extend thence across the plateau towards Ramsey. Exposures may be seen in the ravine under the Skyhill farm, where again the rock is traversed by dykes (see Mr. Watts's Appendix, p. 596); and on a smaller scale in the bed of the tributary on the opposite side of Glen Auldyn, north of the old lead-mine. But while in the last-mentioned locality the material is presented as a series of streaks a few feet across, it has in the next exposure, $\frac{3}{4}$ mile distant, in Elfin Glen immediately south of the town of Ramsey, a breadth of outcrop of about 300 feet. If, therefore, these form parts of the same band, a rapid expansion north-eastward is indicated, which again would be explicable by presuming the plane of brecciation to have been folded.

From Elfin Glen the structure is prolonged towards the sea in the broad ridge of Ballastowell, where it terminates within 150 yards of the coast-line against a low terrace of drift. Nearly the whole bulk of this ridge, between Ballure Glen and the cliff-like slope overlooking Ramsey, is composed of coarse crush-conglomerate, the width of which, as measured on the map, is between 700 and 800 feet, and its depth, from the lowest to the highest point seen, about 300 feet. The various stages in the formation of the structure by the shattering of flaggy sandy slates are beautifully exhibited in the weathered crags east and west of the Albert Tower; and the material itself is extensively quarried as a building-stone at the seaward end of the ridge.

In the talus of a small quarry near the farmstead of Ballastowell, on the summit of the hill, Mr. H. Bolton obtained the cast of a trilobite,[1] referred to on a previous page. By the kindness of Mr. Bolton I have been able to examine this specimen, and were it

[1] Geol. Mag. 1893, p. 29.

not for the definite pronouncement of palæontologists to the contrary, I should have been inclined to doubt its organic origin, and to consider it the cleavage-marked cast of a lenticle of grit. The presence of an isolated fossil in a rock of this character might perhaps be explained by supposing that it was separated out from its matrix during the breaking-up of the bedding, and preserved its existence throughout as an independent 'pebble.'[1] But the occurrence is rendered the more curious by the fact that the closest search has hitherto failed to reveal similar fossils in the unbroken strata.

The Skiddaw rocks emerge rather suddenly in the cliff about 300 yards east of the termination of the Ballastowell ridge, and there consist of crumpled blue argillaceous slates. There is a narrow strip of the crush-conglomerate, 20 to 30 feet wide, in the little headland 150 yards farther east, apparently let down between two strike-faults; but, as mentioned above, the main mass is cut off from the coast-section by the drift-terrace.

In summing up the evidence thus presented, I have full confidence in stating that the breaking-up and re-arrangement of once-continuous strata on a large scale by earth-movements is proved beyond doubt. But the general stratigraphical relations of the crushed material are less clearly established; and in attempting to deal further with this part of the subject I can, at the most, hope to make a preliminary essay with the evidence in hand, in the expectation that future work will supply the requisite proof or correction.

V. The Stratigraphical Relations of the Crush-Conglomerates.

In the above descriptions attention has frequently been called to the proximity to the brecciated zones on the one side of contorted gritty beds, and on the other of more purely argillaceous slates. These conditions, though not quite universal, are so common as to constitute an important factor in the consideration of the structure. In fact I have come to look upon the junction of such masses of different lithological character as essential to the formation of the crush-conglomerate, and where in a few instances I have not been able in the field to detect this relationship, I have considered that the inability was probably due to the obscurity of the sections, or to later faulting or other complications. In any case, a question of the utmost importance has been whether the grits and slates flanking the breccias represent the same horizon throughout, or whether they, in the different exposures, represent the individually distinct members of a variable succession. Unfortunately the evidence at present available is not convincing either way; though I may state

[1] [That there is nothing improbable in this supposition is abundantly proved by the statement of Mr. McHenry, in the discussion on this paper, that fossiliferous pebbles do occur in a crush-conglomerate in Ireland. See p. 598.—Aug. 4th, 1895.]

that my impression, based on the evident repetition of some of the beds by folding, is that there is approximately only one horizon represented in the various conglomeratic bands, but that this horizon has been somewhat modified by a considerable variation in the thickness of the strata involved in the disruptive process. Nevertheless the lithological character of the Manx slates as a whole calls for great caution in dealing with this matter. Over large areas, both on the coast and in the interior, we find beds intermediate in texture between grits and shales, composed usually of alternating laminæ of impure argillaceous and fine-grained arenaceous material, often in vividly contrasting pale grey and blue-black tints; and among these rocks thin bands of grit or quartzite frequently recur, both isolated and in groups. No sharp line can be drawn between such rocks and the true grits, on the one hand, and the dark-blue smooth argillaceous slates on the other. Even beyond the limits of these intermediate beds and well within the region of the blue clay-slates themselves, we shall find that layers of dark grit a few inches in thickness are not infrequent, showing that the source of the arenaceous material was still open. Under such conditions we cannot but expect to meet with some interchangeability of lithological type, and the development of sandy rocks in one place and of shales in another on the same horizon.

In spite of this, however, we find that the central ridge of the Island, including all the highest summits, is from end to end built up almost entirely of one type of rock, a smooth, dark, much sheared and imperfectly cleaved clay-slate, which from its occurrence both in North Barrule and South Barrule—hills 16 miles apart, at the opposite ends of the range—I propose to name 'The Barrule Slates.' We find also that the flags and grits are distributed chiefly on either flank of these Barrule Slates, with an ill-defined intervening zone of banded rocks of intermediate texture, and that the flaggy series, or its associated banded slate, is reached in most of the deeper valleys. And this arrangement leads me to think that, taken as a whole and in a broad sense, the gritty rocks of the Island do form a definite stratigraphical horizon, and that the variable beds mark the vertical passage from this sandy set into the slaty series. It is evidently in these passage-beds that the brecciation has chiefly taken place; and where the crush-conglomerates are very thick, as in Sulby Glen, it appears probable that the intermediate series has been almost entirely disrupted and redistributed as a shear-breccia between the Barrule Slates and the fundamental grits.

(1) Method of Formation.

We return to surer ground in discussing the method, and the age, of the brecciation as revealed in the intimate structure of the crush-conglomerates.

Not even the experimentalist could devise a better material for rendering evident the effects of earth-movements than the colour-

banded portions of the flaggy slates and grits above described. In them every plication and shear-plane is brought out with the greatest distinctness, so long as any vestige of the original bedding remains. Consequently, in such beds, where the exposures are at all satisfactory, the making of the crush-conglomerates can be followed from the first simple folding of the strata to their final rending asunder and redistribution. If the layers had been all of one colour and composition, I can conceive that the brecciation might have taken place, and yet after the impression of the later cleavage have been quite imperceptible to the observer. Indeed, in examining weathered faces of the almost homogeneous Barrule Slates, in which definite phacoids are sometimes marked out by shear-planes, it is permissible to surmise the existence of such masked brecciation. But usually a closer search will reveal some faint signs of distorted stripe in adjacent crags, sufficient to show that if such hidden brecciation do exist it is not very widespread. And I think we are safe in concluding that the structure is developed on a large scale only in rocks of a definite petrological type, and in them only under definite conditions.

In tracing the banded strata towards the area of brecciation, we may note in them many features foreshadowing their impending disruption (see Mr. Watts's Appendix, p. 589). The planes of strain-slip become more distinct, and their effect upon the bedding more important. Thus, for instance, in a stretched portion of the rock, as illustrated in fig. 2 (p. 568), while the slaty layers still retain their continuity, the less plastic sandy bands are seen to be cut into segments by the strain-slip planes, and these segments are dragged apart, forming a string of lenticles.

A similar effect, though differently brought about, is produced where the rock has been pressed and packed into a narrower compass, as in fig. 3 (p. 570), where amid a general thickening of the slaty layers the gritty seams have had their individual segments pushed more or less edgewise, and even an occasional fragment pinched clear away from the bedding-plane.

In other instances there has been along each strain-slip plane an oblique shift, or small step-fault in the grit-band, so that these layers assume a cable-like aspect, and the surfaces look as if deeply ripple-marked, as in the example illustrated in fig. 4 (p. 571).

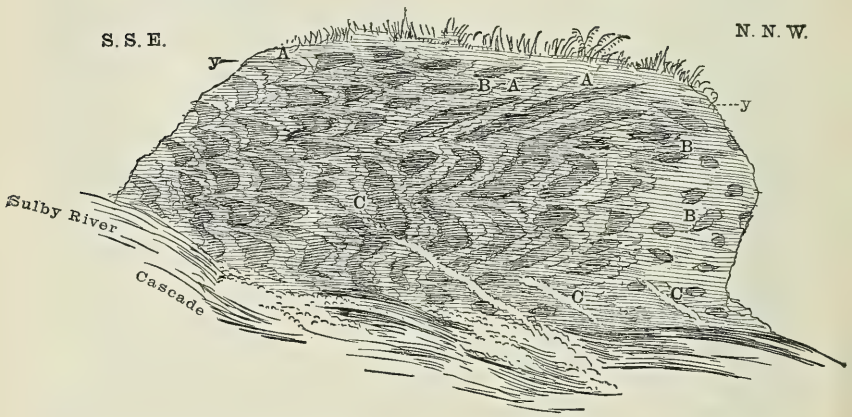
In other cases, though more rarely, instead of this simple sliding of the individual fragments one over the other, there seems to have been a partial rotation of each upon its axis, probably as the combined result of end and side pressures, as illustrated in fig. 5 (p. 571).

It is clear that in any of the above cases a slightly greater displacement of the relative position of the fragments would have annihilated the original bedding-planes and produced a crush-conglomerate. And that this is what has actually taken place is fully proved by many sections in which all the different stages of the process stand revealed; as in the crag shown, by way of example, in fig. 11 (p. 582).

In a few places the banded rocks, either from some peculiarity

of lithological composition or from altered conditions of stress, seem under the shear-pressure to have yielded equally throughout, and in such instances the bands are now and again spread out and obliterated for a short space, so that, as shown in fig. 6 (p. 571), the only structure recognizable in the slaty mass is the shear-cleavage. In this case it is not easy to distinguish between the effects of the earlier and the later shear-pressures. The re-arranged rock, however, so closely resembles the matrix surrounding the inclusions in the crush-conglomerates, that I think it may safely be considered a local modification of the brecciation-stage of the earth-movements.

Fig. 11.—*Sketch-diagram showing passage of banded slate into breccia. Western bank of Sulby River (Glen Mooar) under cottage opposite Slieaumonagh. (Length = 12 feet.)*



Firm blue and grey flaggy slates, with well-marked banding A A A, highly contorted in the centre and left side of the crag, and broken up into more or less rounded fragments (B B B) in a slaty matrix on the right and upper part. The thickness of the bands is somewhat exaggerated in this figure. C C C. Quartz-veins, 2 to 4 inches thick, disturbed and twisted, but continuous across the breccia. *y–y*. The later shear-cleavage. The direction of movement was probably from S.E. to N.W.

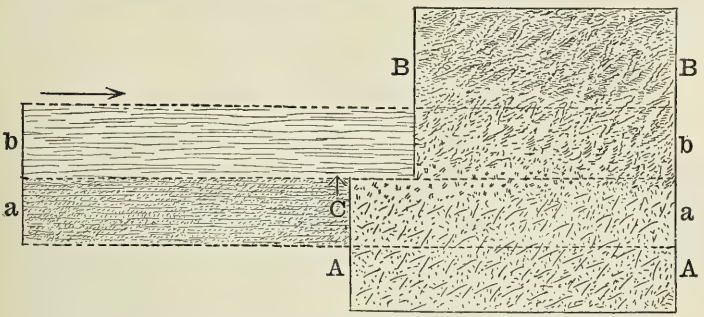
Further evidence might, if necessary, be brought forward; but I think that sufficient has been given to prove that the formation of these pseudo-conglomerates, both in regard to matrix and inclusions, has been brought about by differential movements in a variable rock-mass. It has also been shown that the conglomerates occur chiefly along the junction of strata of different lithological composition. And the evidence points to there having been, during the brecciation of the rock, along with much sliding some actual rolling or milling of the broken material.

Considering that, in the probable original arrangement of the Skiddaw strata as a whole, there has been an underlying platform of grits with an overlying mass of argillaceous deposits, and that

these rocks have together suffered intense deformation, it seems not unlikely that the differential movement to which the crush-conglomerates bear testimony has been the result of the different degrees of compressibility of which these two distinct types of rock are capable. On a small scale this difference is clearly illustrated in some of the sections above described, and its effect upon a broad scale must have been very considerable.

If, under the influence of a powerful lateral thrust, the slates were forced into narrower bounds than the same pressure was able to induce in the grits, a partial rending asunder of the interlocked masses and a shearing of the one over the other must have inevitably followed. Under such conditions I imagine the crush-conglomerates to have been produced, through the breaking-up of the passage-beds, as shown in the accompanying diagram (fig. 12). Except for the

Fig. 12.—*Diagram to illustrate the possible result of strong lateral pressure upon a more compressible argillaceous series, resting on and passing into less compressible sandy rocks.*



a–a (between dotted lines)=space originally occupied by the gritty beds.
b–b (between dotted lines)=space originally occupied by the argillaceous beds.
A–A=Grits after compression. B–B=Slates after compression.
C. Zone of shearing and brecciation.

Note.—The beds are supposed to be driven in from the side indicated by the horizontal arrow.

presence of these passage-beds, and the absence therefore of a sharp line of demarcation, it is probable that the strain would have found relief in the formation of a great thrust-plane, or a series of such planes. Instead of this, the rending force was distributed through a large thickness of rock, which was thereby shattered.

The occurrence of the conglomeratic structure at one side only of the stratigraphical axis is an important point which I shall not seek at present fully to discuss. It appears to indicate the existence of some such definite relationship between the general structure of the Island and the brecciation as I have suggested above. On the opposite side of the axis there seems to be a fairly well-defined zone of slates apparently altered, especially in the vicinity of thick

grit-bands, by thermal metamorphism, although not visible in contact with any igneous mass (see Mr. Watts's Appendix, p. 590); but within the strike of this zone the chief granitic outbursts of the Island occur; and I am hoping that it may hereafter be found possible to bring into intimate connexion the whole of these phenomena.

In my attempts to make out the direction of the fluxion-movements during the formation of the crush-conglomerates I have not been very successful. The later shearing which the rock has undergone and the contortions into which it seems to have been thrown during and after the brecciation, render the results uncertain. There is a very general elongation of the inclusions in the direction of strike, but I am not sure whether this took place during the earlier or the later movements. The force which caused this elongation seems usually to have acted from the N.E. to the S.W. points. In a few instances I have thought that there were vague indications of a primary S. or S.E. to N. or N.W. movement of the larger inclusions, but these are quite insufficient to give a basis for generalized statement. The solution of this point also will probably be found in the study of the Skiddaw rocks of the Island as a whole.

(2) The Age and Duration of the Crushing.

Within the limits of the Isle of Man there is scanty evidence whereby to fix the age of the formation of the crush-conglomerates. Since the earth-movements affected the slate-rocks as a whole, the period must have been of later date than the deposition of the uppermost beds of the Skiddaw series; but in the present state of our knowledge this does not enable us to go further than to state that the crushing must be of later date than Cambrian times, or perhaps than Lower Silurian. The only available upward limit is that to be found in the relation of the slate-rocks to the Basement Conglomerate of the Carboniferous strata on Langness, where the character of the unconformability is such as to show clearly that the Skiddaw Slates had assumed their present structure and aspect before Carboniferous times.

Within these wide limits the Island supplies no closer data; but in the not far distant and structurally connected regions of the Lake District, the east coast of Ireland, and the Southern Uplands of Scotland we know that very extensive earth-movements, affecting rocks of similar age and characterized by similar intensity of plication, took place at the close of the Lower Silurian epoch, and were renewed after the deposition of the Upper Silurian strata.

With regard to the duration of the pressures, I think there is abundant evidence in the crush-conglomerates themselves that the brecciation was not produced suddenly, but by a force acting slowly, and probably intermittently, during a considerable period. The beds seem first to have been thrown throughout into acute plications, during the formation of which there was time for an

extensive 'creep' of material from one part of the fold to another, as shown by the thickening of the layers in certain portions and their attenuation elsewhere. Subsequently when the folds were closed up and could no longer yield, the pressure gradually overcame the cohesion of the bedding-planes along certain zones of intense shearing, and the folded rocks were broken into fragments.

Some of the larger fragments in the breccias still retain traces of the initial movements, the slaty inclusions in which the original bedding remains occasionally exhibiting a crumpled structure and also, more rarely, an obscure cleavage, which does not coincide in direction with any of the structures of the surrounding matrix.

At some period after the accomplishment of the brecciation, possibly after an interval of long duration during which the older dykes were injected and many of the quartz-veins formed, the pressure again became sufficiently powerful to affect the structure of the rock. In this instance, however, the displacement of the particles took place only within very narrow limits of space; and its effect was to produce a rude shear-cleavage, affecting the crush-conglomerate equally with the uncrushed rocks and the greenstone-dykes. The force of this later pressure can be best gauged by the condition of the quartz-veins in the brecciated area. These frequently occur as torn strips along planes of movement, or as wavy plicated strings; but always, like the dykes, definitely crossing the crush-conglomerate (see fig. 11, p. 582), and I have sought in vain for any fragments of either in the breccia. This seems sufficient proof that neither dykes nor quartz-veins were in existence when the brecciation-movement took place, and that the disturbances which both exhibit belong to the later period. It is, however, necessarily difficult to differentiate out the work of the several stages thus superimposed, and I do not profess to be able in every case to make the distinction.

Many later displacements have also undoubtedly affected the area, both in pre-Carboniferous and in post-Carboniferous times; but these have produced only the ordinary effects of simple faulting, and have no direct bearing upon our present subject.

VI. Similar Rock-structures elsewhere in Great Britain.

So far as my somewhat imperfect search has gone, I have not been able to glean much information bearing upon these structures[1] from the literature of the older rocks of Great Britain; and yet have found sufficient to show that, as might have been surmised from the widespread distribution of rocks of similar lithological type to the Skiddaw Slates, similarly folded, there is nothing in any way peculiar to the Isle of Man in the occurrence of these crush-conglomerates, although it is probable that they are not often displayed

[1] The question of the 'augen-gneisses' is not dealt with, since—although there are certain points of resemblance to the crush-conglomerates—the general characters of the rocks are quite distinct.

on so extensive a scale. And since I know that it is not in every section that the true nature of the structure becomes apparent, there seems much likelihood that 'conglomerates' of this origin have not always been recognized as such.

In the highly disturbed Devonian rocks of the south-west of England Mr. J. E. Marr has described[1] the production on a small scale of separate 'eyes' of limestone and of grit by the folding and breaking-up of thin bands, exactly as in the Manx strata.

It is certain that similar brecciation occurs on an extensive scale in some parts of Ireland. It has been described in the Cambrian rocks of the north side of Howth by Prof. Sollas,[2] and in the metamorphic rocks of South-west Donegal by Mr. J. R. Kilroe.[3] In the last-mentioned instance, indeed, there seems to have been more fluxion-movement and less actual brecciation than in the Manx rocks; but in other respects there is close similarity, even to the occurrence of two separate periods of earth-movement with an intervening stage during which certain igneous rocks were injected. It is important to notice, however, that while the sheared rocks of Donegal have been highly metamorphosed there is comparatively little mineral alteration in the crush-conglomerates of the Isle of Man (see Mr. Watts's Appendix, p. 591); and it follows that the rending and crushing alone are not sufficient under every circumstance to bring about extensive metamorphism.[4]

I am also permitted to state that Messrs. Marr and Harker have found during the course of their work among the Ordovician rocks of the Lake District, that in certain localities the strata have been extensively broken up by earth-movements, as in the Isle of Man, though under somewhat different conditions.

[Since this paper was read my attention has been kindly called to the following references to the subject, previous to those mentioned above, which had been overlooked.

In discussing, in 1877, the supposed unconformity at Llanberis, Prof. T. M'K. Hughes remarks[5]:—'The coarser and more sandy beds were crumpled and contorted, while the finer beds were compressed and cleaved, and, being thrust into the folds of the harder beds, gave the appearance of a denuded jagged edge of slaty rock.'

In a paper read at the same time Dr. H. Hicks says[6]:—'The curious change in the rocks which he has taken for an unconformity is probably, as suggested by Prof. Hughes, only an appearance due to rock-structure, not uncommon in beds of unequal texture and

[1] 'On some Effects of Pressure on the Devonian Sedimentary Rocks of North Devon,' Geol. Mag. 1888, p. 218.

[2] Proc. Geol. Assoc. vol. xiii. (1893) pp. 92–93 & p. 170.

[3] Mem. Geol. Surv. Ireland, Expl. Sheets 22, 23, 30, & 31 (S.W. Donegal), 1891, pp. 13–42. [See also Mr. McHenry on the Portraine and Balbriggan areas in the discussion to this paper, p. 598.]

[4] Is it not possible that the time-element may in this respect be a factor of prime importance, and that where the crushing has gone on very slowly there has been a concurrent dissipation of the generated heat?

[5] Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 143. [6] *Ibid.* p. 150.

SKETCH-MAP OF THE
ISLE OF MAN,
to illustrate paper on the "Crush-Conglomerates,"
by G. W. Lamplugh, F. G. S.
English Miles.
0 1 2 3 4 5 6
I R I S H
S E A
Gob ny Creggan Glassey
Gob y Deigan
Corrally
PEEL SANDSTONE
PEEL
FIG. 2.
CONTRARY HEAD
NIARBYL SLATES
River Neb
St. Jo
Foxdale
Dalby
NIARBYL PT.
SOUTH BARRULE 1585
RANGE
Gob Bread
Fleshwick Bay
Silver Burn
Port Erin
CARBONIFEROUS AREA
CASTLETOWN
Port St. Mary
SCARLET STACK
Castletown Bay
LANGNESS
CALF OF MAN

N.B. *The long streaks show the extent of the Crush-Conglomerate.*

SKETCH-MAP OF THE
ISLE OF MAN,
to illustrate paper on the "Crush-Conglomerates,"
by G.W. Lamplugh, F.G.S.
English Miles.
0 1 2 3 4 5 6
IRISH SEA
POINT OF AYRE
Kirk Bride
Andreas
Jurby
DRIFT PLAIN
RAMSEY
Sulby River
Ballure Glen
Ballaugh
Glen Mooar
MAUGHOLD HEAD
NORTH BARROULE
Port Mooar
Kirk Michael
Cornah R.
Gob ny Creggan Glassey
Gob y Deigan
SNAE FELL 2034
Dhoon Bay
Corvally
Injebreck
Luxey R.
PEEL
Laxey Bay
CONTRARY HEAD
River Neb
St Johns
CLAY HEAD
Foxdale
R. Glass
R. Dhoo
Dalby
NIARBYL PT
SOUTH BARROULE 1585
DOUGLAS
Gob Breac
Fleshwick Bay
ST ANN'S HEAD
Port Erin
CARBONIFEROUS AREA
CASTLETOWN
Port St. Mary
Scarlet Stack
Castletown Bay
LANGNESS
CALF OF MAN
N.B. The long streaks show the extent of the Crush-Conglomerate.

extent, cleaved so as to crumple the hard beds and thrust the cleaved slates into the folds.'

Two years later Prof. Hughes again mentions the subject in a paper 'On the Altered Rocks of Anglesey,'[1] in which are the following suggestive passages (pp. 341 and 342):—'When we have subordinate hard unyielding beds which are incapable of . . . . . extension, they are broken up and discontinuous'; and again (on p. 344):—'When on a small scale nodules, or on a large scale masses, of hard rock lying in compressible shale are subjected to contortion, the shale is squeezed out over the harder masses, producing a kind of fault all round between the harder and softer rock, and giving rise to slickensides and similar phenomena,' etc.

In 1883 Prof. T. Bonney, in a paper in this Journal,[2] described and figured the first stages of the breaking up of grit-bands interbedded with slate, the phenomena resembling those dealt with in the Appendix to the present paper.

In America Mr. C. R. Van Hise has described[3] a 'friction-conglomerate' 10 feet wide, in the Baraboo Quartzite of Central Wisconsin, 'the fragments having been ground against one another until they have become well rounded'; and furthermore, we read that 'the rock has been affected by at least two dynamic movements, separated by a considerable interval of time.'

It is probable that there are records of other instances abroad which have not come under my notice.

Attention may also be called to a short description of similar structures in the recently-issued 'Petrology for Students'[4] by Mr. Alfred Harker.—July 18th, 1895.]

VII. Concluding Summary.

The chief points brought forward in this paper may be epitomized as follows:—

(i) In the Skiddaw Slates of the Isle of Man strata of considerable thickness have been locally broken up under shear-pressure, and re-arranged in the form of a crush-conglomerate or friction-breccia.

(ii) This crush-conglomerate occurs in definite bands striking with the surrounding rocks, sometimes continuous for many miles.

(iii) The brecciation has usually taken place along the junction of arenaceous with argillaceous strata, and has chiefly affected the passage-beds between such rocks.

[1] Proc. Cambridge Phil. Soc. vol. iii. pt. viii. (1880) p. 341.

[2] Quart. Journ. Geol. Soc. vol. xl. (1884) pp. 19, 20, and fig. 9 with pl. i.

[3] 'Some Dynamic Phenomena shown by the Baraboo Quartzite Ranges of Central Wisconsin,' Journal of Geology, Chicago, vol. i. (1893) pp. 351–52.

[4] 8vo. Cambridge, 1895, p. 281.

(iv) The formation of the crush-conglomerate has occupied one stage only in a series of earth-movements which had previously folded the rocks and afterwards impressed a shear-cleavage upon them.

(v) There is reason to believe that the crush-conglomerate marks a definite stratigraphical horizon; and that it was originally dispersed in a rude zone which afterwards suffered contortion.

PLATE XIX.

Sketch-map of the Isle of Man, on the scale of 4 miles to the inch, showing the outcrop and strike of the crush-conglomerates.

APPENDIX.—PETROGRAPHICAL NOTES *on the* 'CRUSH-CONGLOMERATES' *of the* ISLE *of* MAN. By W. W. WATTS, Esq., M.A., F.G.S.

[PLATES XX. & XXI.]

As most of the rocks collected in the Isle of Man by Mr. Lamplugh have passed through my hands, it has fallen to my lot to describe the specimens of 'crush-conglomerate' for him. At his request I add to his paper a few notes on the macroscopic and microscopic characters of selected examples of these specimens. The microscopic observations appear to confirm, in all essential points, the deductions drawn by him from the field-evidence. They even enable us to go a little further on some points:—to trace the disintegration of the grit-bands; to watch the process of 'pebble'-making on a small scale; to see the breaking-up of the 'pebbles' themselves into miniature 'crush-conglomerates'; to follow the erosion of the 'pebbles' into single grit-particles involved in slate; and, finally, to state the amount of secondary change which the rocks have undergone.

It will be convenient to divide these notes under the following heads:—

(1) Sedimentary rocks outside the great area of movement and crush.

(2) The 'crush-conglomerates': (*a*) as a whole; (*b*) their contained fragments.

(3) The dykes penetrating the conglomerate.

(4) Metamorphism of the 'crush-conglomerate.'

(1) The Sedimentary Rocks.

It is very rare to find in the Skiddaw Series of the island any sedimentary rocks, except those of very coarse grain, which have not been crushed and sheared by earth-movements. Outside the principal zone of crush and brecciation the rocks still possess their original clastic structure, but they begin to show, by much deforma-

tion, shearing, and cleavage, the influence of those movements which have produced such grand results in the great crush-zone itself. These rocks may be regarded as the raw material out of which the 'crush-conglomerates' have been manufactured.

I do not propose to give a full microscopic description of each specimen, only of those which are of prime importance, merely referring to the principal features which are to be observed in the other specimens. The sediments are best illustrated by the following examples:—

[E. 2403.[1]] Glen Dhoo Stream, nearly 2 miles west of Sulby Glen. A crushed grit.

[E. 2414.] Eastern side of Glen Dhoo Stream. Grit cut into 'pebbles' which are only just being disconnected. (Pl. XXI. figs. 1–3.)

[E. 2427.] Same locality. Close-grained grit.

[E. 2415.] Roadside, S.E. of Snaefell. Striped and puckered slate.

[E. 2416.] Traie ny Foillan, Maughold. Striped sandy shale, frilled and sheared.

[E. 2403.]—A dark-grey, compact grit, with veins running parallel to the shear-planes. Microscopically this grit is seen to be made up chiefly of quartz-grains with a smaller quantity of felspar and a few bits of detrital mica and tourmaline. The largest grains measure ·02 inch in length, but the average size varies from ·005 to ·007 inch in length. In part of the slide the grains show the effects of crushing, and have become phacoidal in shape; the shear-planes which curve round them are marked by sericite-flakes. The matrix, in which the grains are set, is a very fine-grained aggregate of quartz-grains, calcite, and minute scales of sericite; the latter mineral, from its relation to the fragments, occasionally encroaching on even the larger grains, must be a secondary product.

[E. 2427] is a still finer grit, which is more crushed than that last described, so that all the grains are phacoidal in shape and are set in a plexus of minute flakes of sericite and pale-brown mica. It has evidently undergone some chemical change.

[E. 2414.]—The two slides cut from this specimen are extremely instructive, as they show fine puckered slate in contact with fine-grained grit, just the kind of junction which one would expect from Mr. Lamplugh's observations to throw light on the progress of the crushing. The junction is irregular—rounded promontories of the grit projecting into the slate, and fine crushed shreds of slate running into the gulfs and bays between.[2] Occasionally bits of grit are quite isolated from the main mass, and form, as it were,

[1] The numbers in square brackets are those of the slides in the collection of the Geological Survey.

[2] The figures and description given by Prof. Bonney (Quart. Journ. Geol. Soc. vol. xl. 1884, pp. 19 & 20, fig. 9 & pl. i.) deal with a phenomenon which is precisely similar to this.

islands in the slate. Where this occurs the straits of slate are highly puckered and often have a fine strain-slip cleavage developed in them, which does not, however, penetrate into the grit. These divisional planes vary in direction in different parts of the slide and appear to be here merely a local phenomenon, due to the pinching of the slate in the jaws of the grit. They bear no relation to the incipient separation of the grit-promontories into islands, which must be attributed to another and an earlier movement.

The dividing of the grit-band into fragments can almost be watched in the two slides cut from this specimen. The *disjecta membra* vary in size, from fairly large patches to those which contain only a few grit-particles, and even these are beginning to go to pieces, so that one is compelled to believe that many of the separate grit-particles in the slate, which are evident strangers there, have been floated off from the grit-band, and are the ultimate term of the disintegration. The illustration shows admirably the size of these fragments and their gradual disintegration down to actual single grit-particles. (Pl. XXI. figs. 1, 2, & 3.)

[E. 2415.]—This specimen shows alternate bands of grit and slate on its cut surface, and the microscopic slide gives an excellent example of the 'cleavage-foliation' of Sorby. The strain-slip cleavage runs at right angles to the stripe, and the cleavage-planes are planes of foliation marked by a deposit of pale brown mica. Where the quartz-grains are large enough to be well seen they have a phacoidal shape, but in the coarser bands the quartz is in complex grains arranged parallel to the foliation. There is a diversion of the cleavage-planes in traversing the grit-bands. The rock is a mica-schist.

[E. 2416.]—The stripe of this specimen is a plane which has been minutely puckered and in the slide it is seen to be crossed, at an angle of about 60°, by a strain-slip cleavage in the slate-bands. In places the grit is torn off and forms lenticles in the slate. Pale brown mica is developed along the planes of stripe, in the slate-bands, and it runs into the strain-slip planes in wavy surfaces. The amount of mica present here is very great, but there is much less in the grit-bands. A few colourless needles which I take to be felspar occur in the slate, and a few needles of tourmaline are also present. A great quantity of ilmenite, in fine, needle-like crystals, occurs scattered quite irregularly all over the slide; it has no definite orientation. The shredding-out of the coarse beds is observable, but the fragments remain along the line of stripe.

One or two other specimens which have been examined show knotted structure and the development of garnet, mica, and ilmenite. In one case at least this alteration appears not to be connected with any igneous mass, for the rocks are all well exposed in two valleys, one on either side of the col on which the specimen was collected.

(2) 'The Crush-Conglomerates.'

The slides from the crush-conglomerate belong to two groups—those which are taken from individual fragments or 'pebbles,' generally the larger ones, and those which show the microscopic aspect of the conglomerate itself and its smaller 'pebbles.'

The fragments exhibit a great uniformity in composition, and nothing has hitherto been found in them but grits and slates. Now, Mr. Lamplugh has shown by field-evidence that the location of the brecciation has been settled, in the majority of cases, by the existence of thin grit-bands in slate forming a transition between the main grits below and the slates above, in the Skiddaw Series. The fragments found in the crush-conglomerates could all be matched either in this transition series or else in the main grits or slates. Although Mr. Lamplugh was alive to the importance of looking out for the existence of fragments of igneous rock and other strangers, and collected a number of specimens to be tested with this point in view, not a single fragment of any other rock has been up to the present detected. To enforce this point five specimens of grit-fragments have been selected for description, and will be dealt with after the characters of the conglomerate have been described.

(*a*) Two specimens and four slides of the 'crush-conglomerates' have been chosen for description:—

[E. 2413.]—Lowest crags on eastern side of Sulby River, at Cluggid Junction. (Pl. XX. figs. 1–4.)

[E. 2412.]—Druidale Stream, north of Close. (Pl. XX. fig. 5.)

A remarkable feature about these rocks is that, in spite of the immense amount of mechanical disturbance which they have undoubtedly undergone, they have suffered comparatively little mineralogical change. The specimens previously described exhibit locally much more mineral change than has been detected in the zone of crush, so that the amount of change found in particular specimens of the conglomerate, such as [E. 2412], need not necessarily be connected with the actual brecciation. A specimen to be subsequently described will show that the conglomerate itself has sometimes suffered from a later thermal metamorphism.

[E. 2413.]—This specimen breaks with a slabby fracture, which is seen on the cut surface to correspond to a banding of the specimen, at the first glance resembling bedding. This direction corresponds with a grit-band traversing the fine slaty material in the middle of the specimen. Parallel with this, on each side, run one or more bands of conglomerate, generally consisting of light-coloured fragments in a darker matrix; some of the fragments are, however, darker than the matrix. Traversing all these bands at an angle of about 30° or 35°, runs a close cleavage, the planes being lead-coloured and marked by a deposit of exceedingly fine chloritic matter. This is the 'shear-cleavage' of Mr. Lamplugh, and its intersection with the slabby structure produces a streaking on the

surfaces of the latter. The slide described is cut at right angles to all three structures.

Turning to the slide, the fine band is seen to be a grit made up of angular quartz-grains varying from ·002 to ·001 inch in length. The coarse bands are conglomeratic, and consist of fragments from ·100 to ·125 inch long, dispersed in a slaty matrix: this frequently contains grit-particles set in a fine-grained, fibrous material, which appears to be chiefly chlorite. A fine slaty substance of this description makes up the fine dark laminæ which separate the conglomerate-bands from the grit and from each other.

The fragments in the conglomerate-bands are made up chiefly of grit similar to that just described, of still finer grit, and of slaty rock in which mica is rather freely developed. No fragments of igneous rocks, or indeed of any other rock than those just mentioned, have yet been discovered in the crush-conglomerate.

Signs of great crushing are at once observable throughout the slide; faulting, contortion, and cleavage are all present, and the quartz-particles in the grit, and especially those in the slate, are nearly all phacoidal in outline.

Turning next to the divisional planes to be seen in the slide, the following phenomena are important. Taking the main grit-band as a direction of some significance, and without stopping to enquire exactly whether it represents bedding or what not, we find that it bears no relation to other very important structures of the rock. The 'shear-cleavage' of Lamplugh is well developed throughout the rock, and especially in the finer-grained portion. It is a true contortion-cleavage, and it appears to be the same as 'ausweichungs-clivage' and the 'strain-slip' cleavage of Bonney. This structure, when best developed in the slaty matrix, is at an angle of about 30° to the general direction of the grit-band; it runs in the same direction in most of the slate-fragments. It is noteworthy that it is only in such fragments as have their laminæ at right angles to the strain-slip direction that the structure is at all characteristically shown; these alone show contortion clearly. Those otherwise orientated are merely crushed, and do not display so clearly the reason for the cleavage-planes which traverse them. The difference of 30° in the direction of the lineation of the rock and of its cleavage shows that the latter structure is to some extent independent of the former.

That the 'shear-cleavage' has acted on the rock when it was a 'conglomerate' is evidenced by two facts. When an edge of a fragment is at right angles to the shear-cleavage the fragment and the matrix are seen to have been contorted and even faulted together (see Pl. XX. fig. 4). The shear-cleavage is perfectly developed only in the slaty matrix and slate-fragments, and very imperfectly in the gritty fragments and bands. When, however, there has been exceptional movement and crush, the planes travel into the coarser constituents from the finer (see Pl. XX. fig. 3).

On the other hand, that the movement (a shearing movement) of the fragments through the matrix had not ceased is not improbably

shown by the distortion of the planes of shear-cleavage where the matrix has been much nipped between two adjacent fragments. (See Pl. XX. fig. 1.)

When, however, an attempt is made to assign each structure in the rock to the earlier or the later movements very great difficulties crop up, chiefly owing to the tendency there would be for the shear-cleavage to follow the lines of weakness initiated by the first crushing of the rock.

That the 'conglomerate' is cataclastic and not epiclastic might have been, I think, predicted from the examination of the slide and specimen. In the first place, the nature of the conglomerate, slate- and grit-particles in a slaty matrix is, to say the least of it, a very unusual one; it is difficult to see how such a conglomerate could result by a deposit from water. In the next place, the absence of extraneous fragments is most suggestive, all the fragments being such as are found bedded in the Skiddaw Slate Series of the Island. Further, the examination of the shape of the fragments leads to the same conclusion. Working along the slide from right to left one seems to be following a bed of grit; first it is slightly bent, next it is more sharply folded and almost faulted, then nearly pinched off by a sharp wrench, and at last it is actually torn off, and one realizes that one has been tracing a fragment and not a band, or, rather, that one is watching the actual method of forming a fragment or fragments out of a band. This phenomenon is illustrated by Pl. XX. figs. 2 & 3. It may be seen again and again, and in places smaller bits of such fragments will be seen wrenched off and still standing in close proximity to their parent masses.

Few of the fragments in the slides studied are entirely rounded; usually one or two corners are rounded off, while the rest are sharp and angular. When this is the case there is sometimes evidence that the round end of the fragment has moved forward (sheared) through the matrix, distorting the cleavage-planes as it did so. In fig. 4 of Pl. XX. the fragment seems to have moved through the matrix and distorted the 'shear-cleavage,' so that it reminds one of the waves running off the bows of a moving steamer, or the waves in Prof. Boys's bullet-photographs.

A peculiar feature is that some fragments are rounded and 'pebbly' at one end, while at the other they have behaved as matrix and have had other 'pebbles' jammed into them. This is illustrated by figs. 1 & 3, Pl. XX. In this case the reason is obvious: the 'pebbly' end is coarse-grained and resisting, the 'matrix' end is made of finer, softer material.

Without going into further minute detail, the appearance of the slide may be thus summed up:—Fragments are bent, twisted, broken, faulted, and floated off from one another; one fragment indents another, or has another bent or broken over it; wisps and shreds of matrix are caught up amongst adjacent fragments—torn, faulted, and teased out, or rounded and made into 'pebbles' where there is more space for them to move; the matrix and fragments are in places so inextricably mixed up that it becomes impossible

to discriminate between them. A careful study of the illustrations will give a clear idea of the general relations of these two primary constituents of the 'crush-conglomerates.'

[E. 2412.]—A dark slaty rock or phyllite containing fragments of pale grit. The rock splits into slabs, which are at an angle of about 30° to the minutely puckered foliation; these slabs are defined by the 'shear-cleavage.' The elongation of the fragments is in the plane of foliation. Owing to the less-marked character of the second movement, this specimen is very valuable as showing the origin of the conglomeratic structure. Three slides have been prepared: two are in the plane of intersection of the strain-slip with the contorted foliation, and almost at right angles to the elongation of the fragments; they consequently show only the strike of the divisional planes, which appear as cleavage-cracks. The slide has a damascened appearance, owing to the direction in which the mica-folia are cut, and the matrix of the rock is rich in sericite which is clearly a secondary product. The fragments do not show any decisive orientation in these slides, nor do they seem to be in any way related to the foliation-planes.

The other slide [E. 2412 C.], however, is cut at right angles to the cleavage and foliation, and parallel to the elongation of the fragments, so that it is very instructive. The phyllitic matrix is rich in sericite, and is well foliated. The folia are in wavy bands, with the development here and there of strain-slip cleavage-planes which traverse matrix, or fragments, or both, according to the nature of the material of which they are made; such planes define the slabby surfaces of the hand-specimen. The grit- and slate-fragments are all phacoidal in outline, and are drawn out along the foliation-planes, folded, torn, and enwrapped by the folia of the matrix. Fragments are occasionally but rarely cut off abruptly, and even when this is the case with one end, the other is frequently drawn out into the matrix. The nature of the fragments and the absence of any extraneous types of rocks must be relied on here to prove that the brecciation has occurred *in situ*. The whole rock has undergone more mineral change than the specimen [E. 2413] described.

(*b*) '*Pebbles*' *in the Conglomerate*.—The following specimens are described:—

[E. 2409.]—Narradale Stream, W. 5° S. of 838 level on road, Sulby. Fragment measuring 14 feet across.

[E. 2410.]—Sulby Glen under Close. Grit-inclusion in conglomerate.

[E. 2411.]—Sixty yards north of Druidale Junction, Sulby River.

[E. 2419.]—Crag in Sulby Glen, south-east of Killabraggah.

[E. 2421.]—Road-cutting in Narradale, south of stream, Sulby.

[E. 2409.]—This is the largest fragment hitherto found in the conglomerate; it is 14 feet in diameter, and its outer face is smoothed and striated. Within the surface-layer the rock has not

been affected by crushing, as is shown by the character of a slide taken from beneath the crust of the block. Microscopically this slide is seen to consist chiefly of quartz-grains, the largest of which are a little over ·02 inch in diameter. Some of these are rounded and marked off from the matrix by a deposit of dark material. The smaller grains, which are angular, vary from ·01 to ·005 inch in diameter. One of the grains contains a felsitic inclusion, as though the quartz had been derived from a quartz-porphyry, and a few of the grains answer to the matrix of such a rock. Very few grains of felspar, and one or two of detrital tourmaline, are present. The matrix is quartzose, with a little sericite and much chlorite. The rock shows no signs of crushing or shearing, and there is practically no new mineral development in it.

The finer grits [E. 2410 and 2421] have suffered much more from crushing. The first contains abundant grains of felspar, as well as of quartz and muscovite, together with particles of iron ore. Many of the quartz-grains are composite, and have been derived from a granitic or gneissose rock. The grains of felspar are frequently dusty with inclusions and decomposition-products interiorly, but are surrounded by a ring of water-clear felspar in optical continuity with the interior.

The grains average ·006 inch in longest diameter; the fine matrix is made up of quartz, twinned felspar, and muscovite. The smaller grains are arranged with their long axes parallel to the plane of movement, and the matrix is chiefly occupied by folia of sericite which wrap round the grains and are evidently a secondary product due to the movement that the rock has undergone. The patches of iron ores are broken to dust, and spaced out in lines parallel to the movement.

[E. 2421] is somewhat similar, but it is not so much crushed or altered.

The next specimens [E. 2411 and E. 2419] are of great interest because, while collected as single fragments in the conglomerate, it is quite evident that a little further crushing would have converted each of them into many fragments with 'matrix' material between them, and would have incorporated them in the body of the conglomerate.

[E. 2411.]—A coarse, dark, quartzose grit, in which some of the quartz-grains are opalescent. The original sedimentary arrangement of the materials of this rock is entirely lost, and the structures which are left are merely those due to movement. The rock has evidently been a coarse quartz-felspar grit in which quartz predominated, but fragments of slaty and felsitic rocks were also present. The quartz-grains are phacoidal in outline; they often possess undulose extinction, and they have at times an appearance of twinning. They are often made up of one, two, three, or even more inosculating portions, and they can be seen beginning to divide, the separated portions becoming filled with granular quartz, and every transition down to complete granulation can be followed up step by step (see Pl. XXI. figs. 4 & 5).

Even when a grain as a whole has withstood the crushing force,

its edges, and especially its ends, pass into a mass of granular quartz with muscovite. Actually inside some of the grains granulitic patches occur, which I at first mistook for felsitic matter, but which I am now compelled to regard as the products of crushing and granulation. Fragments of striated felspar have been treated in similar fashion, and slaty particles are flattened and dragged out amongst the more resisting fragments.

[E. 2419] is a similar rock, but it contains a larger range of rocks as fragments, such as granophyre, etc., similar to those found in the grauwackes of the Southern Uplands of Scotland.

(3) The Dykes penetrating the Conglomerate.

[E. 2390.]—Quarry at Kerroo Mooar, Sulby. This rock, which has the appearance of a diorite, consists of large irregular masses of plagioclase (oligoclase or andesine) with both albite- and pericline twinning; the edges are very irregular. The granular matrix is chiefly made up of felspar, but it contains a certain amount of quartz, which is associated with calcite, often in large grains. Chlorite is now the sole representative of any ferromagnesian mineral which may have been present: it occurs in masses in which the fibres are arranged in one direction, so as to yield straight extinction. The rock is an altered diorite or dolerite, most probably the latter. It is this rock which has effected the contact-alteration to be presently described.

[E. 2404.]—Dyke, east side of Sulby Glen, in the crags above the bend at Glen Mooar. This rock is a much altered dolerite, in which the felspars are largely converted into mica, while there is a free growth of secondary felspar and quartz. The new felspar is water-clear, and is sometimes twinned according to the Carlsbad law. There are no prominent planes of shearing or cleavage.

[E. 2405.]—Dyke, Glen Auldyn. This rock has entirely lost all its igneous structure. It now consists of a cleaved and sheared mass of mica, calcite, quartz, and limonite. It has probably been an example of the greenstone type of rocks.

(4) Metamorphism of the Crush-Conglomerate.

[E. 2418.]—East side of quarry adjoining dyke [E. 2390], Kerroo Mooar. The fragments in this rock are made of quartzose grit rather coarser than the rest of the rock, which consists of very finely granular quartz, with some felspar, and abundant muscovite-flakes not arranged in any definite direction. The fragments have phacoidal outlines, and some of them are full of pyrites. The abundance and size of the mica seem to indicate that contact-alteration has taken place, and its irregular arrangement is quite independent of the shearing of the rock. As might have been expected, mica is much more freely developed in the slaty matrix than in the grit-fragments.

EXPLANATION OF PLATES XX. & XXI.

PLATE XX. 'Crush-conglomerate.'

Fig. 1. [E. 2413.] Sulby Glen. 'Pebble' in slate matrix, showing diversion of cleavage by it. Also, to the left of this, a hard 'pebble' jammed into the softer part of another 'pebble.' The passage of the strain-slip cleavage into the gritty band is also to be seen. ×10.

2. The same slide. The 'pebble' in this is part of a contorted band, which is itself being pinched up into several isolated pieces. The effect of another hard fragment to the right is also seen. ×11.

3. The same slide.[1] This, the whole slide, shows a band of grit with bands of 'pebbles' and slate on either side of it. The later strain-slip cleavage makes an angle of 30° with the earlier planes of brecciation. It is best seen in the slate, but traverses the grit-band and the slate 'pebbles'; it is, however, diverted by the grit 'pebbles.' ×3·3.

4. The same slide. A slate 'pebble' traversed by strain-slip cleavage. This is due to a contortion which has influenced 'pebble' and matrix alike (see the 'S.W.' margin). ×11.

5. [E. 2412.] Druidale, Sulby. The rock breaking up into phacoidal patches of grit and slate. Development of strain-slip. ×10.

PLATE XXI.

Fig. 1. [E. 2414, B.] Glen Dhoo. Grit- and slate-bands outside the great zone of brecciation. The distorted grit-band is breaking into fragments, and these are again becoming disintegrated into smaller and smaller patches, some of which consist of several quartz-particles, others of only one. ×10.

2. [E. 2414, A.] Another slide from the same rock-specimen. The separation of a 'pebble' from the grit-band and the breaking-down of it and the band into particles. ×17.

3. The whole of the slide [E. 2414, A] to show the ragged edge of the grit-layer and its separation into 'pebbles.' The centre of this is enlarged in fig. 2. ×3·5.

4. [E. 2411.] Druidale, Sulby. Small 'pebble' of coarse grit in 'crush-conglomerate.' The phacoidal outline of the quartz-grains, their incipient granulation, and the 'shredding' of their ends can be seen. Films of crushed slate occur between some of the quartz-grains. ×10.

5. The same, more highly magnified, and seen with polarized light. One quartz-grain shows undulose extinction and the beginning of the granulation, which is carried a stage further at the end of the fragment. The other grain is completely granulated, and in shredding off at the end the granular quartz is mixed with flakes of mica. Granular patches run into and even across the grains. ×17.

DISCUSSION.

The PRESIDENT congratulated the Author, Mr. Lamplugh, who, although absent, had the advantage of so able an exponent as Mr. Watts. In reference to the trilobite mentioned by the Author as having been obtained by Mr. Bolton, he was not aware that it was derived from these altered beds, but he believed it to be a true trilobite, although too imperfect for determination.

Dr. HICKS said that he had listened with much interest to the paper, as the question was one to which he had devoted considerable

[1] Mr. Lamplugh tells me that these illustrations of microscopical structures might stand equally well for pictures of crags and quarries in these rocks.

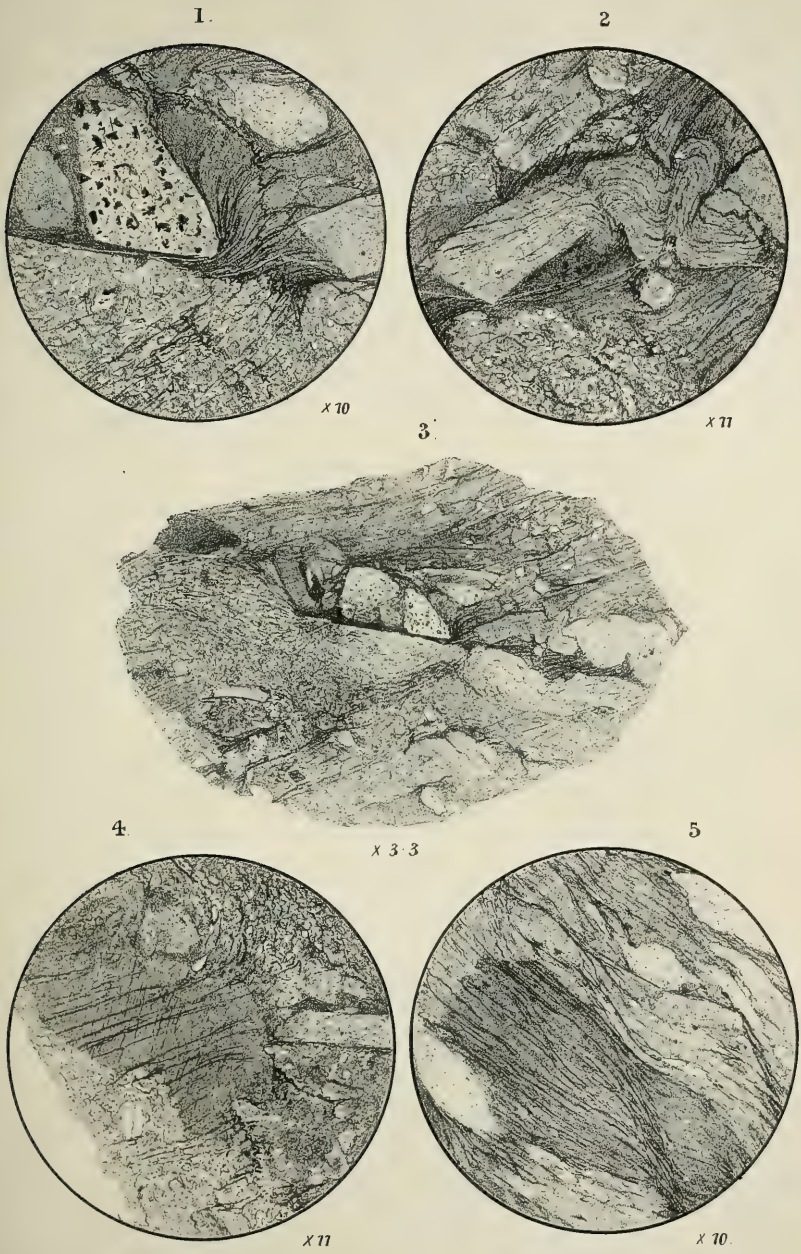
attention. In the references to previous descriptions some important papers by Profs. Hughes and Bonney seemed to have been overlooked. The breccia with large rounded masses in the Dimetian at St. David's was described by Prof. Hughes in the Geol. Mag. in 1883, and in a paper by himself to the Society in 1884, as the 'result of crushings.' Prof. Bonney and he had also come to the conclusion some years ago that many of the augen-gneisses in the North-west of Scotland were produced by the breaking-up and crushing of a massive felspar-rock near lines of fault. The paper by the Author was, in Dr. Hicks's opinion, a very valuable one; for not only did it describe a very marked case, but it also entered more fully into the mode of production than had hitherto been done. He did not like to see the term 'conglomerate,' which has hitherto been confined to a rock with water-borne pebbles, used for this breccia; and would prefer to keep the old term 'fault-breccia.'

Gen. McMahon remarked that the finding of a trilobite in the conglomerate was unfortunate for the Author. Earth-movements had been credited with many wonderful achievements, but that they should produce, as the Author seemed to think, structures so like a trilobite as to deceive the very elect was, if true, a disturbing fact. On the other hand, if we believed the evidence of competent palæontologists, and accepted the trilobite as a clearly recognizable fossil, he was unable to understand how the pressure which had converted slates into breccia, and had subsequently ground the angular fragments into a well-rounded conglomerate, had failed to grind the trilobite out of existence.

Prof. Hughes thought that the peculiar character of the rock was more due to the nature of the 'intermediate' beds, which consisted, where undisturbed, of alternations of thin layers of grit in shale, than to the near contact of the great mass of shale above with the grit below, and that it was an example of the protrusion of an immense number of small pieces of solid rock through a matrix yielding under crush.

Mr. McHenry pointed out that he had recently detected similar conglomerates in the Portraine and Balbriggan areas, which lie along the continuation of the line joining Cumbria with the Isle of Man. These conglomerates are about 500 feet thick, and contain fossiliferous pebbles of the adjacent Silurian limestone, which is also in places partly brecciated. The conglomerates have been considered to be of volcanic origin by Jukes and others, and appear to correspond to those described by the Author in all important particulars.

Mr. H. B. Woodward remarked that beds somewhat analogous to those described by the Author occurred in the Isle of Purbeck. Above the hard Portland Stone and Purbeck 'Caps,' there was a well-known belt of 'Broken Beds,' and in his opinion this was produced by crushing and irregular movements of the strata during uptilting—a view supported by the fact that the layers were disrupted on slightly varying horizons, and that slickensides occurred on surfaces of the Purbeck limestones.



F. H. Michael del. et lith. Mintern Bros. imp.

"CRUSH-CONGLOMERATE" OF THE ISLE OF MAN.

1.

X 10

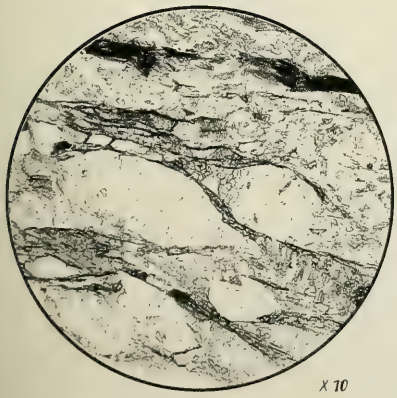
2.

X 77

3.

X 3·5

4.



X 10

5.

X 77

F. H. Michael del. et lith. Mintern Bros. imp.

"CRUSH-CONGLOMERATE" OF THE ISLE OF MAN.

Mr. E. T. Newton thought that there was some doubt as to the so-called trilobite being really organic.

Mr. Marr observed that though somewhat similar results of differential movement had been previously described, the great interest of this case described by the Author was the extensive occurrence of thick masses of a rock simulating a sedimentary conglomerate over wide areas. He believed that many similar rocks had been mistaken for true sedimentary conglomerates in other areas. He noted the discovery by Mr. Harker and himself of rocks having some resemblance to those described by Mr. Lamplugh, amongst the Ordovician rocks of Lakeland. The resemblance, however, was only a general one.

Mr. Watts, in reply to Dr. Hicks, pointed out that the two chief reasons for bringing forward this paper were: (1) that the conglomerate occurred over a wide area, and formed a thick zone, which could be mapped. (2) That the rock was not a mere crush-breccia, but the fragments were often well-rounded. The supposed trilobite found in the talus of a quarry in the breccia was not sufficient to destroy all the other evidence. In reply to Prof. Hughes, he stated that the main grit group of the Skiddaw Series was separated from the Slate Series by a mass of intermediate beds, thin grits and slates, and it was these intermediate beds which have become brecciated by the differential movement at the junction of the two types of rocks. In conclusion, he pointed out that it would be necessary to scrutinize carefully certain cases in which the age of an ancient rock had been determined by the evidence of contained fragments alone.

42. *On the* Occurrence *of* Radiolaria *in* Chalk. By W. Hill, Esq., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read June 19th, 1895.)

[Plate XXII.]

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I. Introductory Remarks.

The rarity of radiolaria in rocks of Upper Cretaceous age is a remarkable fact, and one for which it is not easy to account, seeing that they are not uncommon in Lower Cretaceous rocks on the Continent, and that they have been found in beds of Jurassic age in France, Hanover, and Bavaria. One would moreover have expected the physical conditions of the Upper Cretaceous period to have been more favourable to their existence than those of Lower Cretaceous or Jurassic times. It will be seen, from the descriptions which follow, that one cause of their rarity is undoubtedly the facility with which the siliceous skeletons of *Polycystina* disappear, when they are embedded in rocks which contain a large proportion of carbonate of lime.

Our knowledge of Upper Cretaceous radiolaria comes chiefly from Germany. In 1876 Prof. Zittel described six species,[1] occurring in a Greensand of Senonian age in Westphalia and Brunswick.

In 1888 Dr. Rüst described some well-preserved forms which he had detected in phosphatic nodules from the Gault of Saxony, Hanover, and Southern France, and in material filling the body-chambers of ammonites from the same formation.[2]

He also described *Dictyomitra anglica* from flints in the Upper Chalk of England (*op. cit.* p. 211 & pl. xxviii. fig. 16) and *Dictyospyris chlamydea*, same occurrence (*op. cit.* p. 204).

Besides those in the English flints mentioned by Rüst there are only two records of the occurrence of radiolaria in English Cretaceous deposits. Prof. W. J. Sollas, in 1873, describing the coprolites of the Cambridge Greensand,[3] which were afterwards shown to have been derived from the Gault, says '*Polycystina* and *Xanthidia* occur in some sections,' but he does not figure or describe them. Prof. Sollas has been kind enough to lend us the slides in which these forms occur, but we find that they have well-preserved tests, and differ both in shape and mode of preservation from those which we have found in the Chalk.

In 1883 Dr. Wallich recorded the occurrence of radiolaria in the mealy material found inside hollow flints, mostly obtained from the

[1] Zeitschr. d. deutsch. geol. Gesellsch. vol. xxviii.
[2] 'Palæontographica,' vol. xxxiv. (1888) pp. 181, 185.
[3] Quart. Journ. Geol. Soc. vol. xxix. p. 78.

Surrey gravel-pits.[1] Forms of *Astromma*, *Haliomma*, *Podocyrtis*, and others occur; these also, through the kindness of Prof. Rupert Jones, we have had the opportunity of seeing, and they are all silicified tests, many of them in good preservation.

Several hundred slides cut from almost all the various divisions of the Chalk, from many different localities, have been examined by us, but nothing ever presented itself in any of these which was unmistakably a radiolarian test. Many years ago, however, one of us had noticed that sections through nodules from the Melbourn Rock always contained spherical bodies which had a peculiar aspect, and did not occur in any other kind of Chalk. Being rather inconspicuous and apparently structureless objects, they somehow escaped attention when our joint paper on the Melbourn Rock[2] was being written, and no mention of them was then made.

A few years ago we had the good fortune to obtain and examine a large series of radiolarian earths, chalks, and siliceo-calcareous deposits from Barbados; a study of which made us familiar, not only with the forms of radiolaria as seen in a thin rock-slice, but also with the changes in structure and mineralization which they undergo during the consolidation and partial alteration of the deposits after these have been elevated and exposed to the action of percolating water.

Happening recently to examine some slides of Melbourn Rock again, we were struck by the resemblance of the spherical bodies above mentioned to the form and general appearance presented by calcified and semi-destroyed radiolaria in some of the Barbadian rocks. A careful comparison confirmed the fact of this resemblance, and an examination of other slides disclosed the existence of forms to which the spinous processes were still attached, so that we became convinced of the radiolarian origin of the bodies before us.

Finally some of the slides were submitted to Dr. Hinde, who writes that he agrees with us as to the nature of most of them, and though he at first suggested that some might possibly be diatoms, he subsequently writes that as the spined forms are almost certainly radiolaria it is most likely that the smooth circular bodies also belong to that group, and he would so consider them unless flattened circular *Coscinodiscus* diatoms were proved to be present.

II. The Chalk in which the Radiolaria occur.

The bodies which we take to be radiolaria were first noticed in the Melbourn Rock, and since our attention has been recalled to them we have found them in the nodules of samples of Melbourn Rock obtained from many parts of England. They do not occur in the coarser shelly matrix of that rock, but only in the nodules or lumps of hard fine-grained white chalk which make up so large a portion of the rock.

The nodules of the Melbourn Rock have been described by us in

[1] Ann. & Mag. Nat. Hist. ser. 5, vol. xii. (1883) p. 52.
[2] Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 216.

previous publications,[1] and we regarded them as portions of some pre-existing deposit of chalk-ooze which had gained sufficient coherence to be rolled into lumps on the sea-bottom under the influence of the current which distributed the material whereof the enclosing matrix is composed. We have not changed this opinion, but it would seem that the chalk-ooze which yielded the Melbourn Rock nodules differed from the similar chalk which occurs both at lower and higher horizons, either in the fact of its containing radiolaria or in some special property which was favourable to their preservation.

We have recognized these calcitic replacements of radiolaria in the nodular portions of the lower beds of the Melbourn Rock taken from the following localities:—Melbourn and Royston, in Cambridgeshire; many exposures near Hitchin (Herts); Leagrave, near Luton, in Bedfordshire; Pitstone and Tring, in Bucks and Herts; near Watlington, in Oxfordshire; several localities in Lincolnshire and Yorkshire; in the deep boring at Richmond; in the lower part of the 'grit-bed' at Dover; also at Sutton Waldron, south of Shaftesbury (Dorset); Bincombe, in South Dorset; and quite recently in nodular chalk which may be considered as the equivalent of the Melbourn Rock, from Bindon Cliffs, near Axmouth, Devon.

They do not seem to occur in the nodules of the upper part of the Melbourn Rock, or in those of the Chalk Rock; and though one of us has been constantly cutting samples of chalk from many localities and from various horizons, he has never noticed any such organisms in any other part of the Chalk, except quite recently in nodules from the hard beds of the Chalk Marl in Norfolk, Lincolnshire, and Yorkshire.

One can hardly imagine that the epochs of the Chalk Marl and of the Melbourn Rock were the only times when radiolaria existed in that part of the Cretaceous sea which covered England and France, and it seems more reasonable to suppose that they were frequently present and were embedded in many portions of the Chalk-ooze, but were usually so rapidly and completely dissolved that no trace of them had been left in the consolidated material. Doubtless they contributed to that solution of silica which furnished the substance of the siliceous concretions which we call flints.

We conclude that the preservation of traces of radiolaria in the nodules of the Melbourn Rock is due to some specially favourable conditions, but at present we have seen nothing to indicate what these conditions were. The fact, however, agrees with Dr. Rüst's experience of their mode of occurrence in the Jurassic and Cretaceous rocks of Germany.

In the nodules that we have examined the proportion of radiolarians to the mass of the rock is usually small, but specimens varied considerably. Where these are most numerous the rock may be compared with the calcareo-siliceous deposits of Barbados, which

[1] Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 230, and 'The Geology of London,' Mem. Geol. Surv. 1889, vol. i. p. 521.

contain 12 to 13 per cent. of colloid silica, but this proportion is exceptional, and recognizable radiolarian forms are, as a rule, widely separated.

In the present communication we propose to describe only those forms which we have found in the nodules of the Melbourn Rock, leaving further notice of their occurrence in the Lower Chalk for a future occasion, by which time we may perhaps have discovered some clue to the relation between the occurrence of radiolaria and the formation of the nodules in which they occur.

III. The Instability of the Radiolarian Skeleton.

Slices cut from some of the consolidated deep-sea deposits of Barbados give valuable indications of the manner in which radiolarians are gradually destroyed in the process of fossilization. Those in the more purely siliceous earths do not seem to undergo much change, but those contained in material which is partly siliceous and partly calcareous are more rapidly altered. If a thin section of a calcareo-siliceous rock be viewed by transmitted light, the radiolarian is usually seen in annular outline marked by clear crystalline material (which occupies the position of the original siliceous skeleton), while the interior is filled with a denser, amorphous, calcareous matrix like that of the surrounding rock. The continuity of the clear outline is broken by the pores of the test which, as well as the interior, have become filled with the denser calcareous material. Not infrequently the infilling matter is slightly more crystalline than the matrix of the rock, and, the light passing more readily through it, the outline of the radiolarian acquires greater definition.

But in some cases the interior of the test is filled entirely with clear crystalline material, and it then stands out in strong relief to the darker grey shade of the matrix. Between these two extremes there is every gradation, the lattice-work of the test being sometimes partly visible and sometimes partly destroyed, in others so completely obliterated that nothing but the outline of the test remains for recognition.

The crystalline material infilling the tests of radiolaria in the rocks of Barbados may be either calcite or silica in the colloid state, according to the nature of the rock: calcite where calcite predominates, silica where the rock contains the greater proportion of radiolarians; but often in these mixed rocks the polariscope proves both calcite and silica in the same test. It is evident that the siliceous skeleton of the radiolarian enters into solution and is redeposited in the matrix of the rock, binding its ingredients into a compact calcareo-siliceous mass; this material fills the chambers of the foraminiferal shells and the tests of the radiolaria.

We also observe that the preservation of a radiolarian, even in the form of a cast, depends greatly on the shape and structure of the test. From the examination of a number of slides of the Barbadian rocks we find that Sphæroid, Discoid, and Prunoid tests are the most prominent, the enclosed cell-like character of these shapes seeming to favour the accumulation of glassy material within them.

while the Cyrtoid test is only feebly outlined. Radiolarians with the sponge-like character of the test can be sometimes recognized by a greater opacity of the material within the outline.

While the siliceous network of the test is frequently obliterated in these Miocene radiolarians, one structural characteristic is sometimes retained,—namely, 'the medullary shell.' This is often defined by an inner ring, a clearer central area, or a central area filled with the denser semi-opaque material of the matrix of the rock. Even when the whole test is completely filled with clear material, and no trace of the skeleton is left, the position of the medullary chamber can often be seen. Radiating spines, the striking feature of many radiolarians, are not well shown in sections of Barbados rocks.

Thus it will be seen that, while in calcareous rocks where radiolarians are indubitably present it frequently happens that nothing but their outline remains, our slides show all stages in the transformation of a siliceous radiolarian into a structureless ball or disc filled with calcareous matter or into a mere patch of clear crystalline material. Without the aid of these slides we could hardly have understood how the radiolaria of the Chalk have become so completely obscured as we know them to be.

It must be premised, therefore, that in the forms about to be described the siliceous skeleton of the radiolarian is lost, and the body now visible under the microscope is the section of a cast—either in crystalline granular calcite or in fine calcareous paste. It is this fact which has prevented the earlier identification of the organisms, for all trace of the beautiful radiolarian structure is gone, and nothing remains but a mere patch, which is, however, in most cases easily distinguishable from the surrounding matrix. Many of them have a clearly marked periphery, and others are definite spheres of crystalline calcite, but in no case is there any trace of the actual cell-wall.[1]

This absence of a test is a character which at once distinguishes these radiolarian remains from almost all the other organic bodies which occur in the Chalk, and especially from all kinds of foraminifera, the tests of which are always preserved. Had we not the proof of the manner in which the radiolarian test disappears, it might have been supposed that it would have been simply replaced by calcite, as in the case of sponge-spicules, which are frequently so replaced, though in some parts of the Chalk Marl they remain unaltered.

IV. Description of the Forms met with.

As the chief characteristic of the radiolarians of the Chalk is wanting, the siliceous skeleton having disappeared, it is impossible to refer the various forms we have met with to their respective orders and genera with accuracy, but it is necessary to describe them in some way. Therefore in provisionally arranging them we

[1] Since writing this paper, on examining a slide which had been overlooked, we found a single specimen in which the network of the skeleton can be faintly traced; the silica is entirely replaced by calcite. This form, shown in Pl. XXII. fig. 16, may be referred to the family Liosphærida.

follow as nearly as possible the system of Prof. Haeckel in his report on the radiolarians of the 'Challenger' Expedition, also following Dr. Hinde in his recent description of radiolarians in the Lower Palæozoic Rocks of the South of Scotland, Ann. & Mag. Nat. Hist. ser. 6, vol. vi. (1890) p. 40.

It will be understood that the forms described below are those seen in thin sections of Chalk, and therefore there is the initial difficulty in our being unable to say positively whether the tests are spherical or discoid.

Class RADIOLARIA, Müller.

Subclass SPUMELLARIA, Ehrenberg.

Order SPHÆRELLARIA, Haeckel.

Suborder Sphæroidea, Haeckel.

Family 1. LIOSPHÆRIDA, Haeckel.

Sphæroidea without radial spines on the surface of the spherical shell, living solitary (not associated in colonies): 'Chall.' Rept. pt. i. p. 59.

Genus *Cenosphæra*? (Pl. XXII. fig. 1.)

A simple well-defined circular outline, usually filled with clear granular calcite, but sometimes with denser material (the finer amorphous matrix of the chalk). There is no evidence of radiate spines or of a medullary shell.

Diameter ·22 to ·35 millim.

It occurs in every locality where we have found radiolarians.

Genus *Spongoplegma* or *Spongodictyon*? (Pl. XXII. figs. 2 & 3.)

Another form which we refer to this family is in section a simple, well-defined circle without spines. Within the outline the infilling material is usually dense, and suggests a radiolarian with 'sponge-like' test. In several cases there is a well-marked centre of clearer crystalline material occupying the position of a medullary shell.

Diameter ·25 to ·45 mm.

Localities: Hitchin, Luton, Dover. *Horizon*: Melbourn Rock.

Family 2. ASTROSPHÆRIDA, Haeckel.

Sphæroidea with numerous (8 to 12 or more, commonly between 20 and 60) radial spines on the surface of the spherical shell; living solitary (not associated in colonies): 'Chall.' Rept. pt. i. p. 206.

Forms which we refer to this family are circles with radiating spines, the number of which does not in any case exceed six; these appear to proceed from the surface of the test, and to be irregularly disposed over its surface, not arising in pairs or with any degree of symmetry with regard to each other. The spines are not bristle-like, but have considerable width and length; none seem quite perfect, nor can their junction with the test be seen in every case.

We can do no more than refer them to the family Astrosphærida, there being insufficient detail to place them in any particular genus.

Pl. XXII. fig. 4 shows a circular outline enclosing comparatively clear granular crystals of calcite; periphery clear and unbroken. No trace of medullary shell. Three primary spines arranged unsymmetrically around the test.

Diameter ·35 mm. Length of spines ·37 mm.

Locality: Wilbury Hill, Hitchin. *Horizon*: Melbourn Rock.

Pl. XXII. fig. 5 seems to be the same species, though the general outline is less regular. Five spines are seen, with the base possibly of a sixth. Clear granular calcite occupies the place of the test. No medullary shell.

Diameter ·27 mm. Length of spines ·22 mm.

Locality: Leagrave Road, Luton. *Horizon*: Melbourn Rock.

Pl. XXII. fig. 7 resembles fig. 4. The test is filled with clear granular calcite. Only one primary spine can be seen, though the bases of three others can be made out. There are indications at two or three points of secondary spines. There is also a distinct ring occupying the position of the medullary shell in the centre of the test.

Diameter ·48 mm. Length of spine ·35 mm.

Locality: Leagrave Road, Luton. *Horizon*: Melbourn Rock.

(?) Family Staurosphærida, Haeckel.

Sphæroidea with a simple lattice shell traversed by four crossed and equal spines in one plane.

The two forms which we somewhat doubtfully refer to this family have three spines, two opposite and one nearly at right angles. We assume, therefore, that the fourth spine has either been broken off, or did not come quite within the plane of the section. They do not seem to agree either with the three-spined genus *Spongotripus* of the family Spongodiscida, or with the three-spined forms of the discoidal genus *Triactiscus* ('Challenger' Report, pt. i. pp. 580 & 432).

Rüst figures a three-spined radiolarian from the coprolites of Zilli (*Staurocromyum Muelleri*)[1] which resembles those we describe, except that the pair of spines is not exactly opposite, though nearly so.

Pl. XXII. fig. 6 shows a circular outline filled with dense, amorphous calcareous material, the outer portion marked by a comparatively wide belt of clear crystalline calcite, which is regularly broken by alternate light and dark spaces, probably indicating a shell with large pores. There are faint indications of a medullary shell. Three spines visible, short, broken, the odd one not quite equidistant from the other two.

Diameter ·18 mm. Length of spines ·10 mm.

Locality: Royston. *Horizon*: Melbourn Rock.

Pl. XXII. fig. 15 shows a circular cast, with clearly marked

[1] 'Palæontographica,' vol. xxxiv. (1888) p. 193, pl. xxiii. fig. 8.

outline, filled with finely granular crystalline calcite. No outer band and no medullary shell. Three thin delicate and rather long spines, one pair opposite and the third spine at right angles to it.

Diameter ·21 mm. Length of spines ·23 mm.

Locality: Royston. *Horizon*: Melbourn Rock.

Suborder Discoidea, Haeckel.

Spumellaria with discoidal or lenticular central capsule (often with radial prolongations, rarely allomorphic); with discoidal, or lenticular fenestrated, siliceous shell (often with radial spines or fenestrated arms, rarely allomorphic). Growth reduced or diminished in the direction of one dimensive axis (Haeckel, 'Challenger' Report, pt. i. p. 402).

We refer Pl. XXII. figs. 8 & 9 to the suborder Discoidea. Similar forms are common in sections of the Barbados rocks, but the absence of all structure makes it difficult to do more than indicate the suborder to which we believe them to belong.[1] Length ·37 millim.

Localities: various. *Horizon*: Melbourn Rock.

Like Dr. Hinde, we find forms apparently belonging to the suborder Sphæroidea, but not described by Haeckel in his 'Challenger' Report. They are radiolarians with a single spine extending from the surface of the test. To include these Dr. Hinde has instituted a new genus *Dorysphæra*, and to this we refer the following :—

Dorysphæra, Hinde.

Pl. XXII. fig. 10 shows a circle filled with dense amorphous calcareous material, or finely granular crystalline calcite, its limit usually well defined. One long, thin, bristle-like spine.

Diameter variable, ·15 to ·22 mm. Length of spine ·20 to ·35 mm.

Localities: One of the most common forms at Hitchin, Royston, Luton, Dover, Richmond Well, 702 feet.

Pl. XXII. fig. 11 is very similar to fig. 10, but the single radial spine is much thicker at the periphery of the test and diminishes to a point at the distal end.

Diameter ·17 mm. Length of spine ·13 mm.

Locality: Hitchin Station railway-cutting. *Horizon*: Melbourn Rock.

Pl. XXII. fig. 12 is circular in section, filled with dense amorphous material: its periphery being well marked by minute, clear, calcitic crystals. No indications of a medullary shell. A short, strong radial spine, broad at its base, terminating in a point. The minute calcitic crystals extend outside the periphery of the circle, and seem to mark the position of small secondary spines.

Diameter ·16 mm. Length of spine ·08 mm.

[1] Dr. Hinde, however, writes with reference to these as follows :—'As regards form, I should not hesitate in placing figs. 8 & 9 in the genus *Amphibrachium*.'

Locality: Royston. *Horizon*: Melbourn Rock.

Pl. XXII. fig. 14 shows a well-marked circular outline, the walls of the test still faintly indicated, and filled with finely granular crystalline calcite. No medullary shell. A single spine, thin at its base, but clubbed at its distal end.

Diameter ·36 mm. Length of spine ·27 mm.

Locality: Royston. *Horizon*: Melbourn Rock.

The following form is probably imperfect:—

Pl. XXII. fig. 13. In section a circle filled with clear, fine granular calcite. No medullary shell. A single primary radial spine, strong, and markedly twisted. There is no evidence of other spines, primary or secondary.

Diameter ·18 mm. Length of spine ·25 mm.

Locality: Wilbury Hill, Hitchin. *Horizon*: Melbourn Rock.

These are the more striking figures which we recognize as radiolarians of the Chalk; we do not think that the list is by any means exhausted. Many other forms exist in our slides, the outlines of which may possibly indicate other families and species, which further study may enable us to identify; we have only described those of whose identity we have little doubt.

PLATE XXII.

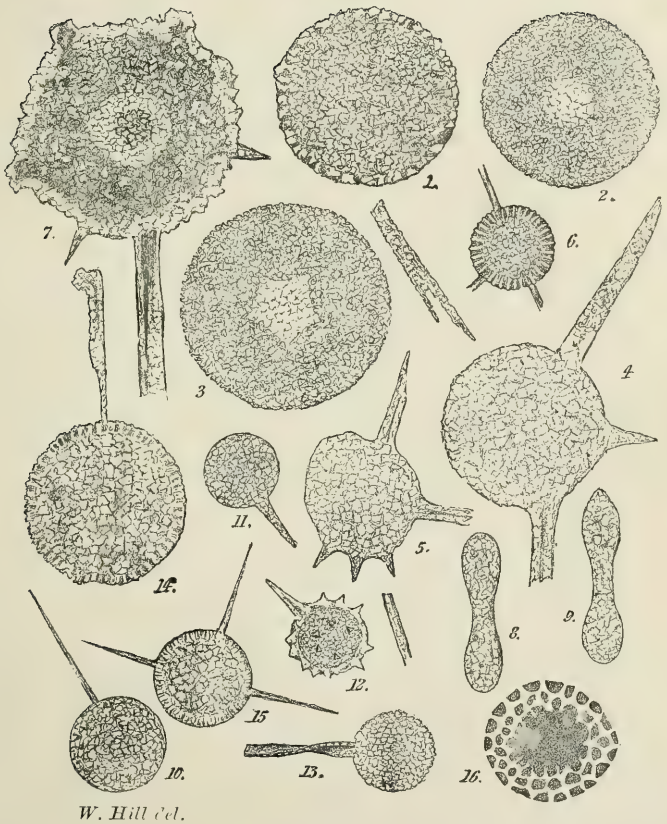
Microscope-sections of radiolaria from the Melbourn Rock.

DISCUSSION.

Dr. G. J. HINDE said that the discovery of radiolaria for the first time in the English Chalk, as distinguished from their occurrence in Chalk-flints, was an interesting fact. One might naturally have expected that some would be present in association with the foraminiferal deposits of the Chalk, but they had hitherto eluded observation, probably owing to the fact that, in common with other siliceous organisms in beds mainly calcareous, their structures were dissolved and only casts now remained, which without careful scrutiny might be passed over as those of foraminifera. He had seen the Authors' sections, and could corroborate their conclusions. The Authors had also done good service in describing the various phases of the fossilization of radiolaria in the calcareo-siliceous beds of Barbados and comparing them with those of the Chalk of this country.

Prof. T. RUPERT JONES stated that, in the Trans. Hertfordshire Nat. Hist. Soc. vol. iii. (1885) p. 152, he had referred to the discovery of *Polycystinæ* in the Chalk,—namely, *Astromma*, *Haliomma*, *Podocyrtis*, and some of the allied *Dictyochidæ*, by Dr. Wallich, in 1883. Some were found in solid flint, and some in flint-meal from hollow flints, from Surrey and elsewhere.

Mr. W. HILL regretted that the communication of Prof. R. Jones to the Herts. Nat. Hist. Soc. should have been overlooked. He thanked the Society for their reception of the paper.



RADIOLARIA FROM THE MELBOURN ROCK.

43. *On a* Well-marked Horizon *of* Radiolarian Rocks *in the* Lower Culm Measures *of* Devon, Cornwall, *and* West Somerset.

By George Jennings Hinde, Ph.D., F.G.S., *and* Howard Fox, Esq., F.G.S. (Read June 5th, 1895.)

[Plates XXIII.–XXVIII.]

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I. Introduction.

The general character and succession of the Culm Measures or Carboniferous series of Devon and adjacent portions of Cornwall and West Somerset, worked out by Sedgwick and Murchison, De la Beche, and John Phillips in the years 1836–1842, have in the main been regarded by geologists as correct; and the alterations and additions to their descriptions which have been made by the subsequent researches of the late Dr. Holl, Mr. T. M. Hall, and of

Mr. W. A. E. Ussher, who has spent many years in investigating this formation on behalf of the Geological Survey, have been principally in the direction of detailed filling up of the outlines laid down by the older geologists.

Stated briefly, the Devon Culm Measures have hitherto been described as consisting of a lower or basal series of dark argillaceous shales, with impersistent intercalated beds of dark limestone, which conformably succeed the fossiliferous shales and slates of the Upper Devonian. Next above this basal series there is a succession of what have been termed fine shaly grits and cherty mudstones, known as the 'Codden Hill Beds.' Overlying these latter there is a further series of sandstones, grits, and shales of great thickness, with occasional thin layers of Culm, which form the higher beds. The entire series of the Culm Measures, as first shown by Sedgwick and Murchison, occupies a synclinal trough between the Devonian rocks of North Devon and West Somerset and those of Mid-Devon or South Devon and Cornwall. The rocks throughout have been highly folded and contorted as well as faulted, and in the southern area bands of tuff and diabase are not infrequent in them. A somewhat scanty fauna is found in the limestones and shales of the basal series, consisting of a few species of *Goniatites*, *Posidonomya*, *Chonetes*, *Spirifer*, and *Phillipsia*, while from the next succeeding Codden Hill Beds only about four or five species of *Goniatites* and brachiopoda have hitherto been known. From the higher portion of the Culm Measures a number of plants and two species of fishes have been determined. It will thus be seen that if we except the thin lenticular beds of limestone in the basal series and the occasional layers of Culm in the higher series, the Culm Measures are at present regarded as consisting of a sequence of detrital or clastic mechanical deposits, which might have been laid down in comparatively shallow waters near a land area.

We have ascertained, however, that the division next above the basal limestones and shales, known as the Codden Hill Beds, is essentially of organic origin, and that it is filled to a great extent with the remains of radiolaria, thus probably forming one of the thickest deposits of these microscopic organisms hitherto known in the geological series. We have made an examination of numerous exposures of the rocks of this horizon at various localities along their line of outcrop in North Devon and West Somerset from Templeton, south-west of Barnstaple, to Ashbrittle, near Wellington, a distance in a direct line of about 31 miles; also on the southern outcrop from near Boscastle on the Cornish coast to Tavistock for a distance of about 26 miles, as well as on the east and south-east of Dartmoor, near Bovey Tracey and Chudleigh: with the result of finding that, throughout, the beds of this horizon are characterized by the presence of radiolaria. We propose in the present paper to give a sketch of the distribution, the principal features and microscopic characters of these Codden Hill radiolarian rocks in the different localities, and to describe the radiolaria in

them, so far as their imperfect condition of preservation will allow. We have not, as yet, had an opportunity of studying in the field the relation of these radiolarian rocks to the beds above and below them, except in one or two instances. As the organic character of these rocks has not hitherto been known or suspected, no strict attention has been devoted to the investigation of the character of the rocks which overlie them, and, owing to their disturbed condition, the succession is not likely to be definitely ascertained until a regular survey of the area has been carried out. We do not profess to have examined all the outcrops of the radiolarian rocks in the Culm area, and it is very probable that these beds will be found in many localities near the northern and eastern margins of the Dartmoor granite, which we have not had an opportunity of visiting.[1]

In addition to the microscopic organisms, certain limited portions of the radiolarian rocks contain other fossils, some of which were collected by Mr. G. J. Hamling, F.G.S., and Mr. G. F. Tregelles of Barnstaple, and obligingly placed at our disposal for examination. In view of the importance of these fossils as showing the geological horizon of the rocks, we have availed ourselves of the kind assistance of Dr. Henry Woodward, F.R.S., P.G.S., to describe the trilobites, and of that of Mr. F. A. Bather and Mr. G. C. Crick to determine the brachiopoda and cephalopoda respectively.

We also wish here to acknowledge our obligations to Mr. J. J. H. Teall, F.R.S., Sec.G.S., for much valuable advice and assistance; to Mr. J. Hort Player, F.G.S., for making two chemical analyses of the rocks; and to Mr. W. A. E. Ussher, F.G.S., for readily affording us needful information respecting the best outcrops of the cherty beds.

II. Literature relating to the Radiolarian (Codden Hill) Beds.

There is no specific mention of the Codden Hill Beds in the important memoir by the Rev. A. Sedgwick and Roderick I. Murchison on the 'Physical Structure of Devonshire and on the Subdivisions and Geological Relations of its Older Stratified Deposits,'[2] read before this Society in 1837, in which the Culm Measures were first described and delimited from the Devonian, or, as it was then termed, the Grauwacke Series. The authors state that the lower beds of the Culmiferous Series consist of black calcareous shale and black limestone with peculiar fossils, which appear on both sides of the great trough. In describing the shales of the Lower Culm[3] as semi-indurated and as having the separate beds divided into innumerable prismatic masses by small transverse joints, while in the softer varieties the masses are generally rhombohedral, and in stating further that they pass into a light-grey, siliceous, jointed flagstone, which in some instances becomes almost

[1] See Postscript, p. 663.
[2] Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1837) pp. 633–687.
[3] *Ibid.* p. 671.

white and porcellanous, resembling a kind of china-stone, it is evident that these authors are referring to the distinguishing features of the Codden Hill Beds, though these are not specially designated.

Although De la Beche [1] gives a section of the lower beds of the Culm and points out that on the northern boundary there is no evidence of unconformity with the Devonian beds below, but a gradual passage from them into black carbonaceous slates and limestones with *Posidonomyæ*, he does not distinguish the Codden Hill Beds, though possibly they are included in the 'shales and slates occasionally carbonaceous, mingled with some grits,' which he says succeed the *Posidonomya*-beds.

The first record of the Codden Hill Beds appears in a paper read to this Society by the Rev. D. Williams [2] in April 1839, in which they form part of the No. 8 of this author's subdivision of the Grauwacke Series. The Codden Hill Grits, as he terms the beds, are divided into grits, limestones, and dark slates. The grits are stated to be lithologically distinct from any other strata in the country, they are slightly calcareous, fine-grained, flinty, thin-bedded, and dark-coloured, but often striped of different tints, and when decomposed resemble hard chalk. The grits are associated with large insulated masses of dark limestone, alternating with black shales containing *Goniatites* and *Posidonomyæ*, and below these are dark slates which gradually pass into the Trilobite Shales of the Devonian.

In a subsequent paper which appears to have been privately printed, entitled 'Tabular Synopsis in descending order of the Succession of the several Members of the Devonian System, as developed in W. Somerset, Devon, and Cornwall,' Mr. Williams further subdivides the Codden Hill Grit into the following four groups in descending order: (*i*) Black, dark, and smoky-grey schists, flags and roofing-slates containing some plants; (*k*) Flint and jasper rock; (*l*) Black-layered, fine-grained grit, almost a lydian-stone, containing a few Crinoidea; (*m*) *Posidonia*-limestone and culmy shales; and the thickness of the whole series is estimated at 1500 to 2000 feet. It is to the divisions *k* and *l* that our Radiolarian Beds belong.

Prof. John Phillips in 1841 [3] pointed out that the base of the carbonaceous group in North Devon consisted of black shales and limestones, with *Posidoniæ* and *Goniatites*, exposed at Venn, Swimbridge, and Bampton, which are overlain by the Codden Hill Beds. These consist of a whitish or grey or black chert in thin striped beds resembling some of the bedded chert of Leyburn in Wensleydale, associated with very soft, white, arenaceous, and argillaceous layers, which contrast greatly with the black bituminous shales of

[1] 'Report Geol. Cornwall, Devon, and West Somerset,' 1839, p. 103.

[2] 'On as much of the Transition or Grauwacke System as is exposed in the Counties of Somerset, Devon, and Cornwall,' Proc. Geol. Soc. vol. iii. p. 115.

[3] 'Pal. Fossils of Cornwall, Devon, and West Somerset,' p. 189.

Swimbridge. He divides the Culm group of Central Devon as below in descending sequence (*op. cit.* p. 194):—

Upper or Grit Group of Central Devon.

Upper Shale Group.—A mass chiefly of dark shales. Carbonaceous grits and shales, the lowest part being the Codden Hill chert series.

Middle or Calcareous Group.—Limestone, mostly black, irregularly bedded, associated with shales, often resting on trap rock, and fossiliferous.

Lower Shale Group.—Black argillaceous plate or very laminar shale, not subject to slaty cleavage, and scarcely fossiliferous.

It may also be mentioned that practically the same sequence of the Culm Measures is given by Phillips in the 'Manual of Geology,' 1855.[1] The Codden Hill cherts and shales are stated to be of considerable but variable thickness, and they are placed with a query below the anthracitiferous gritstone series with plants of the coal-formation and above the black limestone and shale with *Posidoniæ*. In the subsequent edition of Phillips's 'Manual' by Mr. R. Etheridge in 1885,[2] the Codden Hill grits, cherts, and shales are referred to the age of the Millstone Grit.

Dr. Harvey B. Holl in 1868[3] traced out the succession of the Culm Measures in South Devon and East Cornwall, and states that the beds on both sides of the trough are symmetrical, the limestones near the base being precisely similar to those near Bampton in North Devon, and the succeeding grits and cherts resembling those of Codden Hill. The direction of these chert-beds is followed in the Launceston district and also on the east of Dartmoor, between Bickington and East Down, where the chert is to some extent replaced by a siliceous but less flinty rock. Volcanic rocks are associated with the chert and other beds. Dr. Holl likewise describes the slates at Waddon Barton, near Chudleigh, with *Posidonomya* and *Goniatites* as resting on Devonian limestones and overlain by typical carbonaceous sandstones.

In the 5th edition of 'Siluria' (1872) Sir R. Murchison gives a section across North Devon[4] and states that the Pilton and Petherwin Beds of the Devonian are surmounted by true Carboniferous schists with the *Posidonomya*-limestone of Swimbridge and Venn, which is a thin representative of the Carboniferous Limestone and is followed by the Goniatite-grits of Codden Hill, and beds of Culm representing the Millstone Grit series of other parts of England.

In a sketch of the Geology of Devonshire (1878) Mr. Townshend M. Hall[5] refers to the black limestones and shales with *Posidonomya* and *Goniatites* at Venn and Swimbridge, near Barnstaple, as representative of the Mountain Limestone of Derbyshire, Yorkshire, and the North of England, and states that in close proximity to the limestones are beds of whitish shale passing occasionally into a substance resembling porcellanite, with beds and veins of a hard white or grey chert, which are well shown at St. Stephen's Hill

[1] P. 171.
[2] Pt. ii. p. 220.
[3] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 400.
[4] P. 272.
[5] White's 'History, etc., of the County,' reprint, p. 9.

near Launceston, and at Codden Hill near Barnstaple, where they contain *Goniatites* and crinoidal stems.

Messrs. Champernowne and Ussher,[1] in 'Notes on the Structure of the Palæozoic Districts of West Somerset' (1879), describe the Codden Hill Beds exposed at Hulverton Hill, near Dulverton Station, as 'easily distinguishable by their baked appearance, whitish buff or dark-grey colour, and frequent chertoid texture; they consist of thick shales or thin fine-grained grits in tabular layers, so intersected by even joints as to afford a valuable road-metal without further fraction.'

Mr. H. B. Woodward, in the 2nd edition of the 'Geology of England and Wales' (1887),[2] places at the base of the Culm Measure series the shales, thin grits, and impersistent beds of limestone with occasional beds of Culm (*Posidonomya*-limestone) as probably representing the Lower Carboniferous; next above are the Codden Hill Beds (local), probably on the horizon of the Millstone Grit; and succeeding these are the sandstones, grits, and shales, with beds of Culm, which may be of the age of the Lower Coal Measures. The Codden Hill Beds are described as consisting of pale grey or black chert in thin striped beds, with black grits, jasper rock and lydian-stone and a variable thickness of shales, the total thickness of which had been estimated by the Rev. D. Williams at from 1500 to 2000 feet.

Lastly, these rocks have been very comprehensively described by Mr. W. A. E. Ussher in the 'British Culm Measures,'[3] which contains, moreover, a summary and revision of his own previous works[4] on the subject. He divides the Culm Measures from below upwards into Basement Beds, Exeter type, Ugbrooke Park Beds, Morchard type, and Eggisford Grits. It is only with the lower division, or the Basement Beds, that we are concerned in this paper. These consist of the dark limestones and shales and the Chert or Codden Hill Beds. The author considers that Phillips may possibly be right in placing these latter above the shales and limestones of Venn and Swimbridge, and he also assigns the same relative position to the outcrops at Ashbrittle, West Somerset. The typical beds at Codden Hill itself are described as thick, buff, whitish, and dark-grey shales, fine shaly grits and cherty mudstones, and they are stated to be represented in South Devon by hard, thin, evenly-bedded fine grit with an abundance of *Goniatites spiralis*, and, further, it is suggested that the hard beds with *Posidonomya Becheri* and the soft and hard beds at Waddon Barton may belong to the same type. No mention whatever is made of a possibly organic origin of the cherty beds, which are, however, recognized as identical in character with the kieselschiefer of the German and the phthanites of the French and Belgian geologists.

[1] Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 532. [2] P. 197.

[3] Proc. Somerset. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) pp. 111–219.

[4] Rep. Brit. Assoc. (1881) pp. 629–631; *ibid.* (1886) p. 676; Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxv. (1879) pt. ii. pp. 1–20, vol. xxxvi. (1890) pp. 97–104; Geol. Mag. 1887, pp. 10–17; Congrès Géol. Int. 4me sess. Londres, 1888, p. B 141.

III. Distribution of the Radiolarian (Codden Hill) Beds.

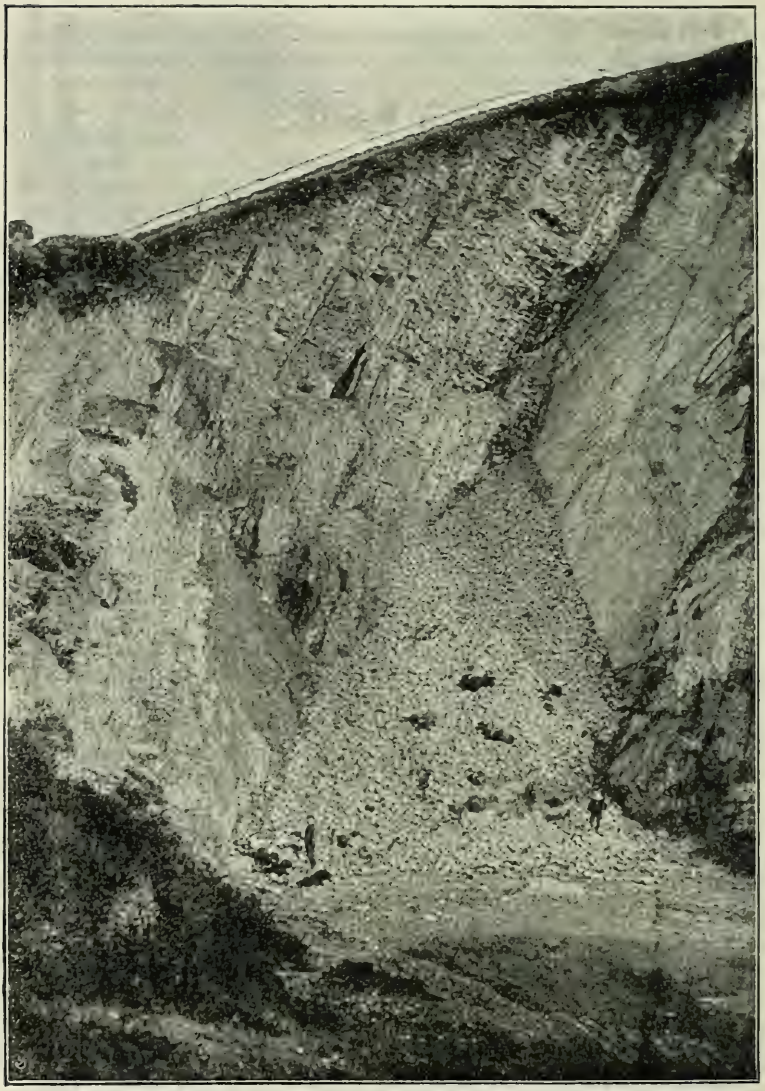
The references given above show that the general petrological characters of the Codden Hill Beds are sufficiently distinct from those of the rocks above and below them in the same series to have caused them to be placed as a separate subdivision by observers who were unaware of their organic characters. But we do not consider that all the rocks which have been referred to this division by Mr. Ussher and other geologists properly belong to it, and we wish further to note that in one particular feature the description given by nearly all previous writers of the character of the Codden Hill Beds materially differs from what we have observed. Thus, it is stated by Williams that they are mainly of 'black-layered, fine-grained grit'; by Phillips that the chert is associated with soft, white, arenaceous layers; Hall conjoins grit and chert; Sir R. Murchison writes of the Goniatite-grits of Codden Hill; and Mr. Ussher also includes fine shaly grits with the cherts and shales of the typical beds. But neither at Codden Hill itself nor at the outcrop of these beds in any part of the Culm area have we met with any description of grit, or shaly grit, or arenaceous shales, associated with the cherts and shales containing radiolaria. There are, it is true, some beds which on ordinary superficial examination bear considerable resemblance to fine grits, but microscopic sections of these show that they are filled with radiolaria and that their supposed gritty structure arises from these organisms, which are more resistant than the soft siliceous shales in which they are embedded.

The Radiolarian or Codden Hill Beds occur along a comparatively narrow zone of country a short distance within the boundary-line of the Culm and the Devonian, which runs in a generally E.S.E. and W.N.W. direction both in North and South Devon. We propose to refer first to the series in North Devon, beginning with the exposures round Barnstaple and then going eastwards to Dulverton, Ashbrittle, and Holcombe Rogus. On the southern boundary of the Culm Measures we commence on the coast near Boscastle and continue eastwards to the district beyond Launceston, and then to Tavistock. On the east of Dartmoor we refer to exposures at Ramshorn Down near Bovey Tracey, at Chudleigh, and at Bishopsteignton near Teignmouth.

(*a*) Barnstaple District, North Devon.

Codden Hill itself may be taken as a convenient starting-point from which to follow the outcrop of the Radiolarian rocks in North Devon and West Somerset. The Hill is situated about 3 miles south-east of Barnstaple, following the high road on the east of the Taw River through the village of Bishop's Tawton. It is an elongate, hog-backed ridge, about $1\frac{1}{2}$ mile in length, running nearly east and west, and between 500 and 600 feet in height. The entire ridge consists of siliceous radiolarian rocks, which are well shown in several quarries on the western and southern slopes. At the western end the principal exposure is known

Fig. 1.—*Section of the Radiolarian (Codden Hill) Beds of the Lower Culm Measures at the Codden Hill Quarry, near Barnstaple, North Devon.*



[From a photograph taken in January 1895.]

as the Codden Hill Quarry (fig. 1). The face of this quarry is about 60 feet in height. The beds are mainly of hard, dark or light grey, sometimes banded, cherty, siliceous rock, with intermediate beds of soft grey or white siliceous shale, which run with an even thickness and in regular succession from the summit to the bottom of the quarry. The dip is 60° N. In the soft shaly beds here the radiolaria can be distinctly seen with a lens, but they are only visible in certain portions of the hard cherty beds.

Overton Quarry, on the southern side of Codden Hill, is almost entirely of white and grey beds, which dip N.E. at 55°, while in the Tower Hamlet Quarry, at the eastern end of the hill, dark and light grey siliceous beds are intermingled.

East of Codden Hill is another elongate ridge, known as Hangman's Hill; at one end of this is Bableigh Quarry, in which the beds dip 60° S.S.W. At the opposite or eastern end of this ridge, on the road leading to Hannaford, is a quarry about 50 feet in height, in which the beds are alternately of dark, hard, compact, siliceous rock and of soft, white, siliceous shales. There are also one or two thin beds of a yellowish or buff, light, porous, siliceous shale or rottenstone containing casts of trilobites and brachiopods as well as empty casts of radiolaria. These latter, associated with hexactinellid sponge-spicules, are also very abundant in the soft white shales, but less recognizable in the harder compact beds. The strata in this quarry are nearly vertical, with an east-and-west strike.

Continuing farther eastward, at Swimbridge, about 5 miles S.E. of Barnstaple, a considerable thickness of siliceous rocks is exposed in a large quarry immediately north of the village. The beds are nearly vertical; they consist mainly of dark, hard, platy, compact rock, but occasionally lighter bands occur in which the radiolaria can be seen with a lens.

Beyond Swimbridge, following the high road for a distance of about 2 miles to the S.E., at the summit of Heddon High Down there are extensive quarries. At the most westerly of these, the beds are almost entirely made up of hard, dull black, siliceous rock with wavellite developed on the joint-planes. They dip 65° N. Some of these black beds are crowded with radiolaria, which are visible, however, only in thin microscopic sections. In the quarries at the eastern end the beds are nearly vertical; the lower ones are of black rock similar to that just mentioned, but above these there is a series of hard, light-grey, or whitish beds, without any admixture of the dark rock. Radiolaria are very abundant in the lighter beds, and they can be readily seen with a lens.

Returning now to the neighbourhood of Barnstaple, on the west side of the Taw River, nearly in a line with Codden Hill, is another ridge, extending for a little more than a mile in a westerly direction as far as Templeton, about 3 miles S.W. of Barnstaple. On this ridge quarries have been opened at Tawstock, Corffe Lodge, and at Templeton. We have not visited these quarries, but from information supplied to us by Mr. J. G. Hamling and from specimens of the beds we have ascertained that the rocks are precisely similar in

character to those of Codden Hill, and, like them, are filled with radiolaria associated with sponge-spicules. At Templeton and at a quarry west of Corffe Lodge, the beds dip north and south on either side of an anticlinal fold of 60°. At Tawstock Quarry also there are thin beds of the light, porous, yellow rock with casts of trilobites and crinoid-stems resembling those at Hannaford.

An outlier of radiolarian rock is exposed at the top of a ridge about a mile due north of Codden Hill itself, in a small quarry near Venn Cross, about one mile S.E. of Barnstaple. The beds here are for the most part hard, and either dark or light grey. They dip S. 15° E. at 45°. In the valley between this Venn Cross ridge and that of Codden Hill are situated the noted Venn quarries of dark limestones and shales, which are now disused and filled with water.

Thus on either side of Codden Hill, from Templeton on the west side of the Taw River to the High Down at Heddon, a distance of about 7 miles in an approximately east-and-west line, there are frequent exposures of the radiolarian rocks.

(*b*) Dulverton, West Somerset.

Eastward of Heddon the next outcrops of radiolarian rocks which we have examined are situated near Dulverton Station, about 17 miles distant. In this neighbourhood there are three important quarries: the most westerly is at Kent's Hill, a prominent conical hill about $\frac{1}{3}$ mile due south of Brushford village. The beds in this quarry are nearly uniformly of hard, dark, platy, siliceous rock, weathering to a slaty grey, without any admixture of soft shales. Only one thin band of the light-grey rock was noticed, which was filled with radiolarian casts. In the dark platy rock the radiolaria can be seldom distinguished, unless in microscopic sections; they are generally associated with sponge-spicules. The beds in this quarry are much less jointed than usual; they are tilted at a high angle, the strike is nearly east and west, and the total thickness of beds shown is about 190 feet.

East of Kent's Hill, a short distance south of Dulverton Station, is Hulverton Hill, a prominent hog-backed ridge, about 670 feet above sea-level, with a quarry on its south-eastern slope. The beds are nearly vertical, with an east-and-west strike, and a thickness of about 100 feet is shown. The beds are mostly of the hard, light-grey variety, but some are dark or speckled dark and white. Soft shaly beds are absent. Some of the lighter beds are crowded with radiolaria, and these can also be seen as whitish specks on the surfaces of some of the darker beds. Messrs. Champernowne and Ussher[1] state that some of the strata here are of thin fine-grained grits in tabular layers; but we failed to find any of this character, and it is probable that the beds referred to are those in which the radiolaria project slightly above the matrix and impart a gritty feeling to the touch.

[1] Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 533.

The third exposure in the Dulverton district is at Blackpool Copse, on the eastern bank of the River Exe, closely adjoining the Exebridge Works, and about $\frac{1}{2}$ mile due east of the Hulverton Hill Quarry. The beds in this Blackpool Quarry are of the same hard, dark, siliceous rock as at Kent's Hill: they have been much disturbed, and dip S. 20° W. at a high angle. Some of the chert is of the striped or Leyburn variety. Very few radiolaria could be seen in this rock with a lens, but thin sections show that these are present in great numbers, and usually sponge-spicules also.

(*c*) Ashbrittle, West Somerset.

A short distance E.S.E. of the outcrop on the banks of the Exe, at Westbrook Farm near Bampton, and at Morebath there are, according to Mr. Ussher,[1] outcrops of shales (or phthanites) similar to the Codden Hill Beds, but these we have not examined. Farther eastwards the radiolarian rocks are shown in a quarry on the summit of a hill $\frac{3}{4}$ mile west of the village of Ashbrittle, on the road to Tiverton. The beds here are very much crumpled and distorted; they are mostly of hard, black siliceous rock, with some thin, soft, shaly beds intervening. In thin sections of the black rock radiolaria are shown in great numbers, and they are present also in some of the soft shaly beds. Champernowne and Ussher mention that the village of Ashbrittle is situated on dark bluish slates or thick shaly beds of the Codden Hill type, and exhibiting its characteristic features in adjacent hill-summits to the west of the village.[2]

(*d*) Holcombe Rogus, Canonsleigh, and Westleigh, N.E. Devon.

A short distance east of Ashbrittle the Culm Measures disappear beneath the New Red rocks; south of it, and thus farther within the boundary of the Culm, are the prominent detached ridges of fossiliferous greyish-blue limestone at Holcombe Rogus, Canonsleigh, and Westleigh. Both Sedgwick & Murchison,[3] and De la Beche[4] as well, point out the differences which these limestones exhibit in the absence of carbonaceous matter and in other features, as compared with the black limestones of Bampton and of the Barnstaple district more to the west, and in general appearance they more nearly resemble the usual types of Carboniferous Limestone, though the occurrence of *Posidonomya* and *Goniatites*, discovered in these rocks by the late Rev. W. Downes,[5] renders it probable that they are, in part at least, on the same horizon as the Bampton, Swimbridge, and Venn black limestones and shales. At the Canonsleigh Quarries, not far from Burlescombe Station, there are cherty masses in the

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 122.
[2] Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 542.
[3] Trans. Geol. Soc. ser. 2, vol. v. (1837) p. 675.
[4] 'Report Geol. Cornwall, etc.,' 1839, p. 105.
[5] Trans. Devon. Assoc. vol. x. (1878) pp. 330, 335.

limestones, and sections of these show faint outlines of radiolaria and sponge-spicules. Some of the limestones are foraminiferal and contain a small form of *Endothyra*.

We have thus traced the radiolarian rocks along and within the northern boundary of the Culm Measures and the Upper Devonian from Templeton, west of the Taw River, near Barnstaple, to Ashbrittle in West Somerset, a distance of about 31 miles in a direct line.

(*e*) Boscastle District, Cornwall.

We now proceed to follow the outcrop of the radiolarian rocks on the southern margin of the Culm Measures, within, that is, north of the boundary-line between them and the Devonian, which is marked on the Geological Survey map as running from near Boscastle on the coast in a generally E.S.E. direction to the west side of the granite of Dartmoor near Tavistock.

As De la Beche pointed out,[1] the lowest beds of shale and arenaceous rocks belonging to the Culm series make their appearance in a bay between the Meachard Rock and Short Island, immediately south of Boscastle Harbour. For a distance of a little more than $1\frac{1}{2}$ mile from this place, in a N.E. direction, the coast-cliffs exhibit a succession of highly folded and contorted slates and grits, having a general dip to the north of about 25°, up to the northern end of what is marked on the 1-inch Ordnance Survey map as Beeny Cliff. At Fire Beacon Point, on the summit of the cliff, 469 feet above sea-level, there is a conspicuous ridge of cherty rock which extends northwards for a distance of 600 feet, and is shown on the slope of the cliff to within 150 feet of the beach. The chert rests on dark fine-grained slates or shales, which can be followed down for a distance of about 150 feet before there is any appearance of grits. The cherty rock itself, making due allowance for the folding of the beds, must be over 80 feet in thickness. It is mainly a very hard, dark or black rock, showing in places lines of lamination; it has been intensely squeezed and contorted, and it is traversed throughout with veins of white quartz. Near the base this rock is interbanded with and gradually passes into hard, dark, fine shales. Under the microscope the dark cherty rock is seen to consist of cryptocrystalline to microcrystalline silica with a considerable amount of dark material, either disposed in laminæ with light interspaces or dispersed generally throughout the rock. In the darker portions there are only a few indistinct casts of radiolaria, but in the lighter specimens they are more numerous, though but faintly shown. On the whole this Beeny Cliff rock might be termed an impure chert, in which the organic structures are nearly obliterated by the admixture of the dark carbonaceous material and the intense pressure.

Above the chert dark shales again come in, and as far as Fox Hole Point, north of Millook, about 5 miles distant from Beeny

[1] 'Report Geol. Cornwall, etc.,' 1839, p. 106, pl. iv. fig. 1.

Cliff, the cliffs show an apparently continuous succession of shales or slates and grits, marvellously folded and twisted and interpenetrated in all directions by quartz-veins, but without, so far as we could observe, any further developments of cherty rock. The dip of the beds throughout this distance is steadily northward, at an average angle of 25°. No mention of this cherty rock near Boscastle is made by De la Beche, although it forms a very prominent feature, and is markedly distinct from the shales above and below. It may also be mentioned that in this district no limestones have been noticed in the Lower Beds of the Culm Measures.

On the high grounds inland, east of Beeny Cliff, angular and subangular fragments of cherty rock, derived from the beds beneath, are scattered over the surfaces of the fields; they are collected, with other loose stones, for road-material, and as a consequence there are no quarry-exposures. One of these surface-fragments from near Ringford, about 2 miles east of Beeny Cliff, showed in thin section casts of radiolaria; also south of Tresparret Down, about 3 miles east of Boscastle, there were piles of stones, some of them from 2 to 6 inches in diameter, partly of the same dark impure chert as at Beeny Cliff and partly of a light reddish chert, laminated, filled with casts of radiolaria, containing also rhomboidal crystals, which in microscopic characters closely resemble the typical radiolarian beds of Codden Hill. Still farther eastwards, near Otterham, about 5 miles in a direct line from Boscastle, surface-fragments of dark chert showed numerous radiolaria in thin sections.

(*f*) Launceston District, Cornwall.

The next locality, east of Otterham, where we have met with radiolarian rocks is at Tregeare Down, a hog-backed ridge 718 feet in height, situated between 5 and 6 miles W.N.W. of Launceston. There are on the slopes of the Down three quarries in a north-and-south line; that at the northern end is small, the beds are mostly of very hard, dark siliceous rock, with a few lighter bands in which radiolaria are readily seen with a lens. The other two quarries are on the south-western slopes of the Down, about $\frac{1}{2}$ mile distant from the first. In these the beds are partly of light grey and partly of dark cherty rock, with some soft shaly beds intervening. The rocks have been more compressed and disturbed than those in North Devon, and the light shaly beds show indications of incipient cleavage, but, with this exception, they resemble very closely the typical radiolarian rocks of Codden Hill. In the southern quarry the beds dip S.S.E. at 60°.

About 3 miles east of Tregeare Down, by the side of the high road leading to Launceston, and near the junction of the Lower Truscott Road, there is another quarry in which the beds are very hard and flinty; some are black or bluish-black, others grey, and there are also some intervening beds of grey shale in which radiolaria are very numerous. The dip is N.N.W. at 22°.

Prof. Phillips[1] refers to the beds at this place as soft and hard, white, pink-stained, and black, the equivalents of the Codden Hill grits, with quartz-veins; below these are laminated grey grits and shales, then thick dark grey or black limestone covered by black shale resting on trap.

Following the high road eastwards along the summit of the ridge, near St. Stephen, about 2 miles from Launceston, are two quarries, one on each side of the road, in which similar hard black and grey cherty rocks with radiolaria are shown. The beds dip W. at 21°.

On the same ridge, north of St. Stephen, in the Castlehill plantation, about $1\frac{1}{2}$ mile from Launceston, is a quarry which on the 6-inch Ordnance Survey map is marked as Barracadoes Quarry (killas). The beds in it, however, are not at all of the nature of killas, but consist mostly of light-tinted, banded, very hard, siliceous rock with interbedded soft, grey, shaly beds, which are crowded with radiolaria and sponge-spicules. The face of the quarry is 20 to 25 feet in height; the beds dip 28° north.

Another exposure of nearly similar chert and shale is shown by the roadside near Dutson, about 1 mile S.S.E. of the Barracadoes Quarry. The beds dip N. 10° W. at 38°. Lenticular patches of volcanic materials are interbedded in the cherty rocks at this place. Some of the beds here have a porous structure, the cavities apparently arising from the dissolving-out of small crystals. Traces of radiolaria can be occasionally seen in the rock, but only after careful search.

According to Dr. Holl,[2] the beds of chert (or radiolarian rock) on St. Stephen's Down and west of it, towards Tregeare Down, occupy the centre of a synclinal trough, the underlying Devonian rocks being brought up to the surface along a narrow axis on the north, which extends from Underwood Farm to Yeolm Bridge, while a lower axis on the south ranges east and west through the town of Launceston.

In a small quarry near Landlake Cross, about a mile east of South Petherwin and $2\frac{1}{2}$ miles south of St. Stephen's Ridge, there are beds of hard black and grey, platy, siliceous rock, dipping E.S.E. at 25°, which contain radiolaria, sometimes in great abundance, and also sponge-spicules, and resemble in other respects the cherty rocks of St. Stephen's Down. As mentioned by Mr. Ussher,[3] these beds are situated within the general boundary of the Devonian, and have been included with this formation in De la Beche's map.

Farther eastwards we next meet with radiolarian rocks at Gordon Hill, a ridge 440 feet in height, about two miles E.S.E. of Launceston, and thus on a parallel more to the south than the beds of St. Stephen's Ridge. On the southern slope of the hill, at the village of Carzantic, is a quarry showing the best exposure of these

[1] 'Pal. Foss. Cornwall, etc.,' 1841, p. 195.
[2] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 410.
[3] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 132.

rocks in the Launceston district (Pl. XXIV.). There is a regular succession of beds, mostly of grey and bluish-grey rocks, but with some of a dark tint as well, consisting of hard, brittle, compact chert without admixture of soft shaly beds. A thickness of about 50 feet is shown, and throughout the series radiolaria can be distinguished, being in some beds thickly crowded together. The face of this quarry is from 40 to 50 feet in height; the beds dip N.W. at 18°. Dr. Holl states [1] that the chert of the high ground of Gordon Hill is underlain on the north by black slate and the limestone south of Timber Bridge.

At Wooladon, on the north-eastern side of the River Tamar, about a mile distant from the Carzantic quarry in a direct line, and close to the Great Western Railway and the river, an extensive section of the Lower Culm Measures is shown in the face of the quarries formerly worked for limestone, which are marked in the 6-inch Ordnance Survey map as Lifton Quarry. The lowest beds exposed are the dark limestones and shales; these are succeeded above by thinly laminated, pyritous black shales containing impressions of *Posidonomya*, followed by a considerable thickness of grey, buff, and white shales, in places separating into thin papery laminæ and minutely porous, which resemble in general appearance the soft radiolarian shales associated with the harder beds which occur in the other quarries of this district, but at this place no organisms can be seen in them. In the lower limestones, however, there are traces of sponge-spicules as well as some rounded bodies resembling radiolaria, but now infilled with calcite.

Above the papery shales, and forming the top beds of the quarry, there are thick and uneven beds of bluish cherty rock traversed by numerous veins of quartz. These are best shown on the southern side of the 'old quarry,' now filled with water, where they dip to the south. Radiolaria are present in this rock, which appears to be the lower portion of the Radiolarian Series, and if, as seems to be the case, the beds are here in their regular succession, they demonstrate a definite upward sequence from the dark limestones and shales with *Posidonomya* through beds of soft shales to the cherty rock with radiolaria. Mr. Ussher [2] refers to this Wooladon section, and mentions that in its upper portion phthanites or Codden Hill Beds are present.

At Lifton Down, about $\frac{1}{2}$ mile due north of the western end of the Wooladon quarry and at a higher level, somewhat similar beds of hard dark and bluish cherty rock, traversed by quartz-veins and accompanied by light siliceous shales, are exposed. The beds are much compressed, and in the chert only a few indications of radiolaria could be seen; but the shaly beds, which have become hard and platy and interpenetrated with numerous minute strings of quartz in the same way as the chert, show in thin sections radiolarian casts in abundance.

[1] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 408.

[2] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxvi. (1890) p. 100; also vol. xxxviii. (1892) p. 127.

On the high ridge of the northern border of Lifton Wood, about ½ mile east of Wooladon, radiolarian rocks are exposed in a quarry at its western end. The beds dip 25° S., and a thickness of about 20 feet is shown. They are for the most part dark, with light or speckled intermediate beds in which radiolaria can be seen with a lens. There is also another quarry, near the Lodge at the eastern end of the wood, showing a section, about 70 feet in height, of very regular beds of black siliceous rock of a platy or kieselschiefer character which dip 12° S S.E. Microscopic sections of the rock show radiolaria in considerable numbers. Mr. Ussher states that the chert (Codden Hill) beds of this locality are overlain by yellowish-brown conglomeratic beds, but these did not come under our notice.[1]

Beyond Lifton Wood we have not traced the radiolarian rocks any farther in an easterly direction, but Dr. Holl[2] states that the chert of Gordon Hill extends as far as Sydenham and Leigh Down to Lew Water, which is 4 miles beyond Lifton Wood.

(*g*) Tavistock District, Devon.

At the east end of Tavistock, ascending Greenhill, above the Tavy Iron Works, a road-cutting has been made for a distance of about 90 yards through massive beds of a dark, hard, compact, finely-laminated siliceous rock. The dip is not clearly shown, but a thickness of over 30 feet is exposed of the cherty rock which appears to rest on dark clay-shales and to be followed by them. The rock is much traversed by quartz-veins and seems to pass gradually into the clay-shale. In microscopic sections the beds are seen to be crowded with casts of radiolaria now filled with micro-crystalline silica.

No other exposure of cherty rock was noticed at Tavistock, but pebbles and rounded boulders of dark siliceous rock, occurring in the bed of the river and in trenches lately opened on its banks, proved, when thin sections were examined, to be filled with radiolaria.

At Artiscombe, about 2 miles west of Tavistock, just beyond the Lumburn Bridge and near the extensive slate quarry of Mill Hill, there is a quarry mainly of a hard, dark, bluish-grey rock in which there were also some thin beds of a laminated grey, platy, siliceous rock, which proved on subsequent examination to contain numerous radiolaria. As the organic character of the rock was not suspected at the time of our visit, its relation to the other rocks in the quarry was not ascertained.

Dr. Holl refers[3] to two small outlying patches of Culm Measures at Painter's or Pentre Cross, near St. Mellion, Cornwall, 8 miles W.S.W. of Tavistock, and 4 miles N.E. of Saltash, as the most southerly point at which the Culm Measures had been observed. At one locality, about 600 yards north-west of the Cross, chert occurs, forming the gutter on the east side of the road. It is hard,

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) pp. 128, 144.
[2] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 408.
[3] *Ibid.* p. 405.

dark or bluish grey, and traversed in all directions by veins of quartz. The rock is filled with radiolaria, some even showing traces of structure. Another small patch of similar chert is seen in the foundation of some cottages on the east side of Vinegar Hill, south of Painter's Cross.

The district north of Stoke Climsland is also stated by Dr. Holl [1] to show chert, but none could be found there. On the high ground just south of this village, however, there are some beds, from 1 to 3 inches in thickness, of partially decayed bluish chert with shales dipping S., but no organisms could be recognized in it.

(*h*) Ramshorn Down, near Bovey Tracey, S.E. Devon.

Passing now to the Culm Measures east and south-east of Dartmoor, in the narrow irregular area between the granite and the Devonian rocks, there is an important outcrop of cherty rocks on Ramshorn Down, a prominent rounded ridge about 3 miles S.S.W. of Bovey Tracey, to which our attention was called by Mr. Ussher. Two quarries are shown by the side of the road which skirts the western end of the Down, one about $\frac{1}{4}$ mile north of the other. The rocks in both quarries are very similar; they mainly consist of very hard, dark, siliceous rocks and a few bands of lighter shaly material, resembling very closely in character those of Codden Hill in North Devon and of the Launceston area in Cornwall. Radiolaria are very abundant in the dark beds and also in some bands of a bluish or brownish tint; sponge-spicules are also associated with them. In the northern quarry a vertical thickness of about 25 feet is shown; the dip is 38°–40° S.E. In this thickness there is but one bed, about 6 inches in thickness, of the light shaly rock; the rest is either dark or bluish brittle rock, or of a platy character. In the southern quarry the cherty beds have been locally crumpled and pushed over one another, and Mr. Ussher has referred to and figured this as an instance of false bedding,[2] which of course would indicate the action of currents during their deposition. But, so far as we could observe, the present disturbed condition of the beds results from mechanical forces acting long after their formation.

Mr. Ussher [3] considers that the chert-beds of Ramshorn Down and its vicinity rest on the Upper Devonian and apparently below the shaly arenaceous beds and *Posidonomya*-bands, and thus on a different horizon from the Radiolarian Beds of Codden Hill and North Devon generally, and from those of the Launceston area, which, so far as present evidence goes, are above the *Posidonomya*-beds. The actual contact of these beds with the Devonian slates has not, however, as yet been seen.[4] It is further stated that the chert-beds seem to pass beneath sandstones and shales with traces of plants, but here again the succession has not yet been definitely ascertained.

[1] Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 404.
[2] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 134, fig. 2.
[3] *Ibid.* pp. 134, 135.
[4] *Ibid.* pp. 134, 144.

(*i*) Chudleigh District, Devon.

To the right of the main road leading from Chudleigh Station to the town, radiolarian rocks are met with in the grounds north of Lawell House. A section of not more than 10 feet in thickness is here shown by the side of a hedge; the beds dip 20° N.N.W. They consist of a dark, hard, compact and brittle siliceous rock, in which there is a small proportion of lime. The rock weathers on the exterior to a dark rottenstone. Radiolaria are fairly numerous and with them are some detached spicules of hexactinellid sponges. We are indebted to Mr. Ussher for directing us to the chert-beds at this place; he states[1] that they occur in faulted association with their surroundings.

At Winstow Cottage, the lodge at the western entrance to Ugbrooke Park, about $\frac{1}{3}$ mile south of Lawell House hedge-section, there is a small quarry showing nearly vertical beds of dark or brownish siliceous rocks of a shaly character, also containing a small quantity of lime. Thin sections show radiolaria and sponge-spicules, and in addition there are fragments of trilobites and crinoid-stems.

Another exposure of radiolarian rocks, for the particulars of which we are indebted to Mr. A. Somervail, of Torquay, occurs about 4 miles north by west of Chudleigh Railway-station, in a cutting just north of Ashton Station. Beds of dark, hard, brittle chert are here shown from 15 to 20 feet in thickness. Hand-specimens of the rock forwarded to us are crowded with radiolaria, which can be seen with a lens. Microscopic sections show that they are only casts, for the most part filled with cryptocrystalline silica, but in some cases with chalcedonic silica. Mr. Ussher has pointed out[2] that cherty kieselschiefer occurs as an inlier of the Codden Hill Beds at Lea Cross, somewhat north of the present locality.

We have not examined further exposures of the radiolarian rocks in the district between Ramshorn Down and Chudleigh, but the road-material largely used in this neighbourhood consists of a hard, white or light radiolarian rock, closely similar in appearance to the Codden Hill Beds—thus showing that not only the dark kinds but the lighter varieties also are developed in the neighbourhood.

(*k*) Bishopsteignton, near Teignmouth, S.E. Devon.

Mr. Ussher informed us of the occurrence of a few beds of chert belonging to the basal Culm Measures, exposed in a rugged by-lane near the eastern end of the village of Bishopsteignton. The specimens of this chert which he has forwarded to us are of a light bluish tint; they are traversed by numerous fine reddish cracks,

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) pp. 133, 142.
[2] *Ibid.* p. 136.

and radiolaria are abundant in them. The beds are very near the boundary of the New Red Rocks; but their relation to the dark shales of this locality (? Culm or Devonian) is concealed.

Respecting the thickness of the Radiolarian rocks generally, we have not at present sufficient grounds on which to base an estimate. The Rev. D. Williams [1] placed the maximum approximative thickness of the series of his Codden Hill Grit, which included not only the Codden Hill Radiolarian Beds, but also the dark shales and limestones (*Posidonomya*-beds) down to the summit beds of the Upper Devonian, at 1500 to 2000 feet, but a large proportion of this would belong to the dark shales. In some of the sections of the Radiolarian rocks exposed in the large quarries of North Devon there is a vertical thickness of from 100 to nearly 200 feet shown. In the southern area the exposures are less extensive, but even here the Carzantic quarry, in the Launceston district, has a thickness of 50 feet of radiolarian cherty rock without admixture of shales. It is very probable that the thickness of the Radiolarian rock may vary considerably in different areas, but it would perhaps not be rash to assume that the Radiolarian Series may be some hundreds of feet in thickness, not all indeed purely organic, but with intercalated beds of fine shales.

IV. Mode of Occurrence of the Radiolarian Rocks.

Both in the northern and southern areas the Radiolarian rocks occur in evenly stratified beds, usually from 2 to 4 inches in thickness, though they range from 1 to 9 inches, and in very exceptional instances to a foot in thickness. The beds are intersected in different directions by numerous fine and even joint-planes which have the effect of dividing the rock up into comparatively small rectangular or rhombohedral fragments with smooth, flat surfaces. It is owing to this feature that these rocks are largely quarried for road-metal, for which the harder beds are well adapted, since in the process of quarrying they readily fall into these cuboidal and rhombohedral fragments, which require very little additional breaking to reduce them to suitable dimensions for this purpose. In spite of these joints, however, the beds usually remain intact until they are actually worked, and in the Barnstaple district and in other places in North Devon quarries are not uncommon with faces from 50 to 70 feet in height, showing a regular succession of these thin, even beds extending uninterruptedly, generally at high angles, from the summit to the floor of the quarry.

[1] 'Tabular Synopsis of the several Members of the Devonian System, etc.'; Mr. Ussher, under the mistaken impression that this estimate referred only to the Codden Hill cherts, etc., and did not include the *Posidonomya*-limestones and shales, says that it could be obtained only by adding an unknown amount of the overlying shales and sandstones to the Basement-beds, Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 114.

Even in the same quarry the radiolarian rock presents itself under very different aspects. Some of the beds are of a very dark or even black, intensely hard, brittle chert with a hackly fracture; others are of a nearly uniform dull grey tint or quite white, but equally hard though less brittle, while yet other beds show alternate light and dark bands which give a striped appearance recalling that of the Carboniferous chert of Leyburn in Yorkshire, with which this rock has been compared by Prof. Phillips.[1] Of a less degree of hardness than those just mentioned are beds of dark to light grey, siliceous, platy rock. In some of these the rock is mottled, patches of dark and white alternate on the same surface-plane, and very frequently the margins of the joint-planes are grey or white while the interior of the rock is dark.

Alternating with the beds of hard chert and platy siliceous rock there are beds, mostly of a white or greyish tint and of a very soft shaly character, which readily break up into thin flakes or laminæ, and in the softest kinds disintegrate when placed in water into a very fine, cream-coloured mud. These soft incoherent beds are filled with radiolaria equally as much as the hard chert, and, as a rule, the organisms can be more easily recognized in the soft than in the hard rock. The soft shales in some instances appear to result from the partial decay of harder beds, for within them there are in places thin layers of a bluish unchanged platy rock. The shales seem to have been less affected by jointing than the harder beds; but, on the other hand, in some localities they show incipient traces of cleavage by delicate parallel lines crossing obliquely the planes of lamination. They are also much less common than the harder rocks; generally a single bed of not more than 1 or 2 inches in thickness intervenes in a considerably thicker series of cherty or platy rock, and in some exposures the very soft shaly beds are altogether absent.

There are numerous gradations between the extremely hard and compact cherty rocks and the very soft shaly beds; not infrequently a very thin lamina of the softer shale is interposed as a partition between harder beds. The central portion of the beds of the cherty rock is generally harder and denser than the exterior layers.

In addition to the regular bedding the radiolarian rocks throughout, both hard and soft, show that they are built up of a series of thin laminæ. These are seen best in some of the light-grey harder rocks, as so many delicate parallel lines of slightly varying lighter and darker tints which succeed each other with great regularity and evenness throughout the beds, thus indicating extremely slow and long-continued conditions of tranquil deposition and consolidation.

[1] 'Pal. Foss. Cornwall, etc.,' 1841, p. 190.

V. Chemical Composition of the Radiolarian Rocks.

We are indebted to Mr. J. Hort Player, F.C.S., for making two analyses of the rocks, which are given below.

	I. *Hard, dark chert from Ramshorn Down.*	II. *Soft, grey shale from Barracadoes Quarry, near Launceston.*
Silica	87·3	67·8
Alumina	5·7	19·8
Ferric oxide	1·3	1·4
Ferrous oxide	1·4	·4
Lime	·3	—
Magnesia	1·2	1·2
Potash	·7	4·8
Loss at 100°	—	·9
Loss by ignition	1·9	3·6
Totals	99·8	99·9

Both these analyses are taken from specimens which, under the microscope, can be seen to contain numerous radiolaria; these were, however, more abundant in No. II. The Ramshorn Down specimen is a typical example of the hard, dark, brittle chert, and, as the analysis shows, the proportion of silica is large. No. II. specimen, on the other hand, is a typical example of the soft grey shales which come in between the harder beds. In this the silica is in less proportion, while there are larger amounts of alumina and potash, the latter originating, as suggested by Mr. Teall, from mica present in the rock. The analysis of a siliceous slate (Wetzschiefer) from the Culm formation at Teufelsberg, near Lautenthal, in the Harz, which contained very numerous radiolaria, is given by Dr. Rüst[1] as silica 69·9, alumina 17·6, soda 3·5. In this rock the proportions of silica and alumina are nearly the same as in the Barracadoes shale, but instead of potash it contains soda.

A marked feature of the Radiolarian rocks is the very general absence of carbonate of lime; even in beds which contain casts of brachiopods, crinoids, and other calcareous organisms, all traces of lime seem now to have disappeared. The only exceptions met with are in some of the rocks at Ramshorn Down and the Chudleigh district, in which a small quantity of lime is present.

VI. Microscopic Characters of the Radiolarian Rocks.

For the study of the rock-structure and the radiolaria we have had about 300 thin sections prepared from the typical rocks in the different localities mentioned above. These show under the microscope a general resemblance in consisting of a siliceous groundmass, in some cases clear and transparent, in others dark and turbid from the presence of fine particles of carbonaceous or ferrous materials

[1] 'Palæontographica,' vol. xxxviii. (1892) p. 111.

Fig. 2.—*Microscopic Section of Radiolarian Rock, showing casts of Radiolaria. From the Lower Culm Measures at Ramshorn Down, near Bovey Tracey, S.E. Devon. From a photograph taken by Mr. J. J. H. Teall, F.R.S.* (*Enlarged about* 35 *diameters.*)

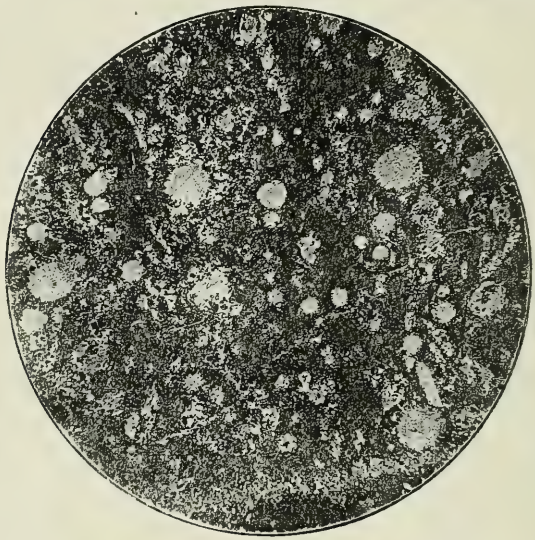
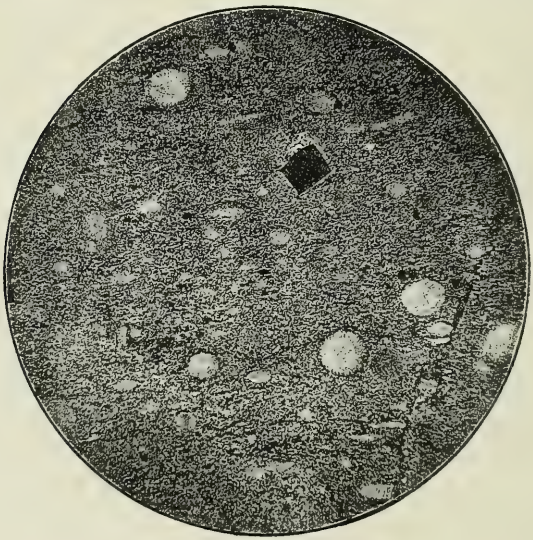


Fig. 3.—*Microscopic Section of Radiolarian Rock, showing Radiolarian casts and a cube of pyrites* (*the dark spot*). *From the Lower Culm Measures at Carzantic Quarry, near Launceston, Cornwall. From a photograph taken by Mr. J. J. H. Teall, F.R.S.* (*Enlarged about* 32 *diameters.*)



and minute crystal-needles of rutile and zircon. The siliceous groundmass in polarized light, between crossed nicols, usually exhibits the faint speckled aspect of cryptocrystalline silica similar to that of a section of a flint from the Chalk; sometimes it is almost entirely dark, in other instances certain bands of the rock in which the radiolaria are very crowded show the lively tints of chalcedony. The radiolaria in the rock generally have been infilled with clear, nearly transparent silica, free to a great extent from the rutile-crystals and the dark substances disseminated in the groundmass, and either cryptocrystalline or microcrystalline in character. Within the radiolarian casts the silica has not unfrequently a radiate fibrous arrangement, and in this case a black cross is shown in polarized light. The more distinctly crystalline structure of the radiolarian casts facilitates their recognition in the rocks with a clear groundmass, where in ordinary light they are scarcely visible, but between crossed nicols they appear as so many circles of speckled or bright light on a nearly dark ground.

These rocks, more particularly the harder and more cherty varieties, very frequently contain minute casts of rhombohedral crystals, ranging from ·015 to ·065 mm. in diameter, which are irregularly scattered in the siliceous matrix. Probably they were originally of carbonate of lime or dolomite, which has now been dissolved and removed. They not only occur in the groundmass of the rock, but also within the casts of the radiolaria enclosed by the siliceous infilling, and in some cases they seem to have become filled with silica themselves. Dr. Rüst[1] notes the occurrence of similar rhombohedra of calcite within the casts of the radiolaria of the Culm in the Harz, and there can hardly be any doubt that the crystals[2] must have been formed where they, or the empty casts, now occur.

Microscopic cubes of pyrites are present in some of the rocks, and, like the calcite-crystals or casts mentioned above, they are not infrequently found within the radiolaria, enclosed by cryptocrystalline silica either singly or in small aggregates (fig. 3). There are, further, in some of the harder and more cherty beds, some very minute rounded bodies, ranging from ·006 to ·013 mm. in diameter, either detached singly or grouped together in small masses; these, in size and other characters, bear a general resemblance to the small bodies in the pre-Cambrian

[1] 'Palæontographica,' vol. xxxviii. (1892) p. 116.

[2] Similar rhombohedral crystals and casts are very generally found in siliceous rocks of organic origin, and the carbonate of lime of which they consist may well have been derived from the remains of calcareous organisms associated in the same rock with the siliceous sponges, radiolaria, or diatoms, but in much smaller proportions. The crystals are likewise found in some siliceous rocks, such as the novaculites of Arkansas, in which no siliceous organisms have as yet been recognized, and Mr. F. Rutley has lately contended that the crystals are merely the residue of an original dolomite or dolomitic limestone which has been replaced by silica (Quart. Journ. Geol. Soc. vol. l. 1894, p. 382). A more probable explanation is that the novaculites were originally organic—the same as the radiolarian beds of the Harz and Devon.

phthanites of Britanny which have been described by M. Cayeux[1] as radiolaria and foraminifera. On this account we have carefully examined them under the microscope, with the kind assistance of Mr. Allan Dick. The bodies in question are now either hollow or filled with colloid silica; their walls are of an amber tint in transmitted light, with bright specks here and there, in some cases resembling perforations. They are apparently formed of a flocculent material without definite outlines, the nature of which is doubtful, but Mr. Dick suggested that it might be a film of limonite remaining after the removal of pyrites. Some of these bodies occur within the radiolaria, in the same manner as the larger cubes of pyrites and the rhombic crystals. There is no evidence to show that they were of organic origin.

The finely laminated character which is so marked a feature of the radiolarian rock is seen under the microscope to be due to regular lines of dark amorphous material and finely granular particles, probably in part carbon and in part a compound of iron. In the darker varieties of the rock this material is so abundant that, save in extremely thin sections, the rock is opaque; but in the lighter and harder varieties it is arranged in alternating bands or laminæ from ·12 to 5 mm. in thickness. The radiolaria are more conspicuous in the darker bands or laminæ than in the lighter, but they are not limited to any particular variety of the rock, and they occur both in the very hard and cherty and in the soft shaly beds.

Thin sections of the comparatively soft shaly radiolarian beds are not materially different under the microscope from the hard cherty varieties. The siliceous matrix is similarly cryptocrystalline; it contains minute cubes and grains of pyrites and needles of rutile, and there are also in it numerous small flakelets of mica. In some beds there are dark parallel lines crossing obliquely the lines of bedding, and between them the radiolaria are often closely packed in regular layers. The radiolaria in these softer beds are, as a rule, in the same mineral condition of solid casts of microcrystalline silica as in the harder rock, and owing to the soft nature of the matrix these solid casts weather out and project, as already mentioned, above the general surface of the rock. In some beds of the soft shales the radiolaria are now represented by empty casts, or these are filled with loose powdery material, and the rock has a light and porous character resembling that of rottenstone.

Some of the shales are sufficiently soft and unconsolidated to disintegrate in water to a milky sediment; the finer portions of this consist of minute siliceous granules, flakelets of mica, and rutile-needles; in the coarser portions are detached radiolaria, but these are usually partially incrusted with the flaky matrix. Under favourable conditions of light, the lattice-structure can be indistinctly seen in some of these detached forms.

Beyond radiolaria and fragmentary sponge-spicules there is a

[1] Bull. Soc. géol. France, ser. 3, vol. xxii. (1894) p. 197; Comptes-rendus Acad. Sci. Paris, vol. cxviii. (1894) p. 1433.

singular absence of other microscopic organisms in these Culm siliceous rocks, and the only forms met with are a few minute dentated plates of a dark or brownish tinge which have a general resemblance to the radulæ of gasteropods. Bodies of a similar character are occasionally present also in the Ordovician radiolarian rocks of the South of Scotland.[1]

In the greater number of the microscopic sections of the Radiolarian rocks which we have examined, detrital materials—beyond perhaps some minute flakelets of mica—are not shown; but in some beds, more particularly in the hard, dark, platy varieties, there is a certain admixture of minute chips of quartz and flakes of mica which appear to be of detrital origin. The particles are very small, ranging from ·03 to ·065 mm. in diameter, and thus not larger than the detrital grains which occur in typical recent radiolarian ooze or in the radiolarian rocks of Barbados. Radiolaria are present in the same rock with these detrital grains, but they are less numerous than in the rocks in which they are not found.

The very generally siliceous nature of the Radiolarian rocks has been already mentioned: exceptions to this occur in the exposures near Lawell House, Chudleigh, where there are some beds of dark limestone alternating with siliceous beds; the limestones contain casts of radiolaria and sponge-spicules which in some instances are replaced by calcite, in others the radiolaria are infilled either with microcrystalline silica or partly with this mineral and partly with calcite. The limestone-matrix is finely granular, and some indeterminable fragments of calcareous organisms are present in it.

We have also examined microscopic sections of the dark limestones which, both in the Launceston district and near Barnstaple, appear below the Radiolarian rocks. The limestone of the Wooladon quarry near Launceston is finely granular, with some traces of calcareous organisms and a few rounded bodies, now infilled with calcite, which may possibly be casts of radiolaria. The dark limestone of the Tinhay quarry, a little farther east, appears to be almost entirely crystalline, and no organisms can be seen in it. A thin section of the black limestone of Swimbridge near Barnstaple was fine-grained and filled with fragments of entomostracan shells and crinoids, also a few rounded bodies of uncertain character. The limestone at Venn, near Barnstaple, is very similar to that at Swimbridge.

The bluish-grey limestones of Canonsleigh, near Burlescombe Station, are very crystalline; they contain, however, foraminifera of the genus *Endothyra*. In sections of the hard, grey, cherty layers associated with these limestones the matrix is of cryptocrystalline silica, in which there are numerous rhombohedra of calcite and casts of radiolaria, precisely similar to those in the normal Radiolarian rocks.

VII. Description of the Radiolaria.

Although there are many varieties of the Culm radiolarian rocks, and these organisms are abundant in all, we have not succeeded in

[1] Ann. & Mag. Nat. Hist. ser. 6, vol. vi. (1890) p. 45.

finding any specimens in which their structural characters are satisfactorily preserved. In the large majority of the Culm siliceous rocks the radiolaria are now in the condition of solid casts of the original forms; their skeletal walls have entirely disappeared and the individual casts are only bounded by the siliceous matrix of the rock and without definite even outlines. In such instances, only the size and general form, with the radial spines, can be distinguished.

In some of the hard cherty and platy rocks of Ramshorn Down and the Chudleigh district the radiolarian tests have been stained of a brownish or amber tint, so that the lattice-like structure can be seen; but they are now so crushed and obscured in a confused mass of broken spines and fragmental débris that it is seldom that a specimen is sufficiently clear to be figured. In other instances the silica of the test is of a pinkish tint, and thus distinguishable from the clear silica surrounding it. For some not apparent reason the tests thus preserved nearly all belong to discoidal forms of *Lithocyclia* and *Porodiscus*.

The radiolaria in the soft, incoherent, shaly beds are in much the same state of preservation as those in the harder cherty rocks—that is, they are mostly casts, and the original tests have been either dissolved or if preserved they cannot in sections be distinguished from the infilling silica.

With radiolaria thus imperfectly preserved determination is extremely difficult; in only a very few instances, as in some of the Discoidea, has it been possible to recognize specific characters; with respect to many, even the generic determination has been a matter of inference. It can be seen that a considerable variety of forms are present in these rocks, and the following Orders are represented—Beloidea, Sphæroidea, Prunoidea, Discoidea, and Cyrtoidea—by 23 genera. Both in the number of the forms and in their state of preservation the radiolaria in our Culm Measures fall far short of those which Dr. Rüst has described[1] from the corresponding formations in the Harz, Sicily, and Russia. Most of these, however, were obtained from two or three small nodules in which the minute structure of the tests was preserved, and should specimens in similar condition be met with in our rocks they would probably be found to contain equally as many species.

Subclass SPUMELLARIA, Ehrenberg.

Order **BELOIDEA**, Haeckel.

Genus Sphærozoum, Meyen.

Pl. XXV. figs. 1 *a*–1 *g*. In this genus there is no latticed test; the skeleton consists of free siliceous spicular bodies, which are now found detached in the rock. According to Dr. Rüst[2] the spicules have four rays extending from a common centre at angles of 120°;

[1] 'Palæontographica,' vol. xxxviii. (1892) pp. 107–192, pls. vi.–xxx.
[2] *Ibid.* p. 133.

but it is very seldom that more than three rays are visible, and these appear to be nearly in a plane. The rays may be either simple and of uniform thickness as in fig. 1 *g*, or swollen at the ends to a bulb or knob as in figs. 1 *c*, *d*, *e*, *f*, or they dichotomize and each branch becomes lobed as in figs. 1 *a*, *b*. They vary considerably in size; a small form is ·03 mm., and a large one ·085 mm. in width. They are generally distributed, and have been recognized at Heddon, Swimbridge, and Kent's Hill in North Devon, at Carzantic near Launceston, and at Ramshorn Down and Winstow Lodge near Chudleigh. Rüst has figured a form resembling our fig. *a* from the Silurian of Cabrières, and he states that the spicules are very abundant in the Devonian and Carboniferous radiolarian rocks of the Southern Ural ('Palæontographica,' vol. xxxviii. p. 133, pl. viii. fig. 11).

Order **SPHÆROIDEA**, Haeckel.

Genus Cenosphæra, Ehrenberg.

The test is a simple latticed sphere, without radial spines. It is probable that most of the rounded casts, abundant in nearly every microscopic section of these rocks, belong to forms of this genus. They vary in diameter from ·065 to ·275 mm. It is only exceptionally that anything beyond the mere outline of the cast is shown in these forms.

Cenosphæra pachyderma, Rüst. Pl. XXV. fig. 2 ('Palæontographica,' vol. xxxi. 1885, p. 286, pl. xxvii. figs. 2, 3). The test is ·165 mm. in diameter and about ·015 mm. in thickness, and the apertures in it are also ·015 mm. in width. From Ramshorn Down. Rüst states that this form is present in all Palæozoic radiolarian deposits, as well as in many of those of Jurassic and Cretaceous age.

Cenosphæra sp. *a*. Pl. XXV. fig. 3. Test relatively large, ranging to ·27 mm. in diameter and ·03 mm. in thickness; the apertures are about ·022 mm. in width. This form is near to *C. ingens*, Rüst ('Palæontographica,' vol. xxxviii. p. 134, pl. vi. fig. 8), but the walls are distinctly thicker. It is common at Ashbrittle, West Somerset.

Genus Carposphæra, Haeckel.

The test consists of two concentric spheres connected by rays. No radial spines.

Carposphæra sp. *a*. Pl. XXV. fig. 4. The outer test is ·14 mm. in diameter, and the inner ·05 mm. Neither the connecting rays nor the lattice-structure has been preserved. A form of nearly similar proportions occurs in the Mullion Island chert (Quart. Journ. Geol. Soc. vol. xlix. 1893, p. 216, pl. iv. fig. 2). Ramshorn Down.

Carposphæra sp. *b*. Pl. XXV. fig. 5. The outer thin test is

·125 mm. in diameter; it is connected by a number of short, stout rays with the inner sphere, which is ·07 mm. in width. *C. macractinia*, Rüst, from the Culm of the Harz, has similar stout connecting-rays, but it is a much larger form ('Palæontographica,' vol. xxxviii. 1892, p. 136, pl. vii. fig. 4). Artiscombe Quarry, near Tavistock.

Carposphæra sp. *c.* Pl. XXV. fig. 6. The outline of the test is now slightly elliptical; it is about ·1 mm. in diameter, the inner sphere is ·05 mm; it is connected by three stout rays. In a boulder from the Lower Culm at Tavistock.

Carposphæra sp. *d.* Pl. XXV. fig. 7. Test now slightly elliptical, with in places a bluntly-spined or dentate margin, diameter ·13 mm.; the inner sphere with a thick wall, diameter ·05 mm.; numerous stout rays connect it with the outer test. Ramshorn Down, South Quarry.

Genus Thecosphæra, Haeckel.

The test consists of three concentric latticed spheres connected by rays.

Thecosphæra sp. *a.* Pl. XXV. fig. 8. The spheres in this form are ·14, ·065, and ·015 mm. in diameter respectively. There are six rays connecting the spheres; probably more were originally present. Hedge section, Lawell House, Chudleigh.

Genus Xiphosphæra, Haeckel.

The test is a simple latticed sphere with two similar free rays or spines, one from each pole.

Xiphosphæra sp. *a.* Pl. XXV. fig. 9. The test is ·06 mm. in diameter, and each of the spines about ·11 mm. in length. Ramshorn Down, North Quarry.

Xiphosphæra sp. *b.* Pl. XXV. fig. 10. The test is considerably larger than the preceding; its diameter is ·13 mm. The spines are stout at the base; they gradually taper, and end obtusely. They are ·09 mm. in length. Ramshorn Down, North Quarry.

Genus Xiphostylus, Haeckel.

Test a simple latticed sphere, with a spine or ray from each pole. The spines are unequal in length.

Xiphostylus sp. *a.* Pl. XXV. fig. 11. The test is depressed spherical, ·11 mm. in diameter; one spine is stout and ·12 mm. in length, the other slender and only ·09 mm. long. Ramshorn Down, North Quarry.

Xiphostylus sp. *b.* Pl. XXV. fig. 12. The sphere is ·12 mm. in diameter; at one pole is a short acute spine, and at the other a much stouter spine of which only the base remains. The test shows traces of the lattice-structure. Ramshorn Down.

Xiphostylus? sp. *c*. Pl. XXV. fig. 13. The test is depressed spheroidal, ·11 mm. in diameter; at one pole is a short conical spine, at the other a double spine apparently springing from a common base, about ·1 mm. in length. Ramshorn Down.

Genus Dorysphæra, Hinde.

The test is a simple latticed sphere with a single radial spine.

Dorysphæra sp. *a*. Pl. XXVI. fig. 9. The test is ·18 mm. in diameter; the spine conical, pointed, ·11 mm. in length. Carzantic Quarry, near Launceston. A form somewhat smaller occurs at Ramshorn Down.

Dorysphæra sp. *b*. Pl. XXVI. fig. 5. The test is ·22 mm. in diameter and ·02 mm. in thickness; spine stout at base, tapering slightly and obtusely ended, length ·18 mm., thickness at base ·03 mm. Ashbrittle, West Somerset.

Genus Acanthosphæra, Haeckel.

The test is a simple latticed sphere, with numerous simple radial spines of equal size.

Acanthosphæra laxa, sp. nov. Pl. XXVI. fig. 6. The test is ·16 mm. in diameter; the lattice-structure is not shown, but within there are traces of six rods radiating from an excentric point. From the margins of the test five long slender spines extend in different directions; the longest measures ·5 mm. This form is not uncommon at Ramshorn Down, but the spines are usually displaced and the test distorted.

Genus Staurolonche, Haeckel.

The test consists of two concentric latticed spheres with four similar radial spines.

Staurolonche sp. *a*. Pl. XXV. fig. 14. The outer test is ·18 mm. in diameter, and the inner one ·05 mm. From the inner sphere two rays extend to just beyond the outer test, where they terminate in minute points; the other two rays or spines are not preserved. Hedge-section at Lawell House, Chudleigh.

Genus Stylosphæra, Haeckel.

Test of two concentric latticed spheres, with a free radial spine at each pole.

Stylosphæra sp. *a*. Pl. XXV. fig. 15. The outer sphere is ·13 mm. in diameter, and the inner ·06 mm.; the spine at one pole is slender and ·1 mm. in length, the opposite spine is stouter and broken off near the base. Ramshorn Down.

Order **PRUNOIDEA**, Haeckel.

Genus Cenellipsis, Haeckel.

The test is a simple elliptical latticed shell, without radial spines. Forms of this genus are very numerous and generally distributed in the Culm radiolarian rocks.

Cenellipsis sp. *a*. Pl. XXVI. fig. 1. Test regularly oval; long diameter ·21 mm., transverse ·16 mm., thickness of wall ·015 mm. Both in form and size this agrees closely with specimens from Mullion Island (Quart. Journ. Geol. Soc. vol. xlix. 1893, p. 217, pl. iv. figs. 5, 6). From Carzantic Quarry, near Launceston.

Cenellipsis sp. *b*. Pl. XXVI. fig. 8. Test elongate oval; long diameter ·2 mm., transverse ·14 mm., thickness of wall about ·02 mm. Codden Hill Quarry, near Barnstaple.

Cenellipsis sp. *c*. Pl. XXVI. fig. 2. Test short oval; length ·17 mm., breadth ·145 mm., thickness of test ·01 mm. From Ramshorn Down and Carzantic Quarry, near Launceston.

Cenellipsis sp. *d*. Pl. XXV. fig. 16. Test regularly elliptical; length ·125 mm., breadth ·1 mm., and ·01 mm. in thickness. Ramshorn Down.

Genus Ellipsoxiphus, Dunikowski.

The test is a simple elliptical latticed shell, with a radial spine at each pole.

Ellipsoxiphus sp. *a*. Pl. XXVI. fig. 10. Test oval, ·22 mm. in length and ·2 mm. in breadth, with a stout, tapering, obtusely-pointed spine at each pole. The spines probably were equal in length originally; the longest is now ·17 mm. From Tregeare Down, near Launceston.

Genus Druppula, Haeckel.

Test elliptical, of two concentric latticed shells without radial spines.

Druppula sp. *a*. Pl. XXV. fig. 17. The test is regularly elliptical; length ·14 mm., breadth ·115 mm., the inner test ·04 mm. in diameter. No connecting-rays are shown. Ramshorn Down.

Druppula sp. *b*. Pl. XXVI. fig. 7. Test regularly elliptical; length ·18 mm., breadth ·155 mm. The inner test is ·07 mm. in diameter; it is connected by numerous rays with the outer. Carzantic Quarry, near Launceston.

Order **DISCOIDEA**, Haeckel.

Genus THEODISCUS, Haeckel.

Test a simple lenticular latticed shell, with three marginal spines.

Theodiscus aculeatus, sp. nov. Pl. XXVI. fig. 3. The test is now partially crushed; originally it seems to have been somewhat oval in outline; the diameter is ·2 mm. The three marginal spines are unequal in length; the longest measures ·5 mm., and ·04 mm. in thickness at the base; there are also some smaller spines. Traces of lattice-structure are shown. This form is allied to *Th. gigas*, Rüst, from the Silurian of Cabrières ('Palæontographica,' vol. xxxviii. 1892, p. 163, pl. xx. fig. 4); the test is slightly larger; the spines are longer but less robust. Not uncommon at Ramshorn Down.

Genus SETHODISCUS, Haeckel.

Test consisting of a lenticular latticed cortical shell connected by radial beams with a simple medullary shell, and having the margin of the circular disc simple.

Sethodiscus chudleighensis, sp. nov. Pl. XXVI. fig. 13. Only a vertical section of this form has been recognized. The cortical test is lenticular, ·15 mm. in length, and ·09 mm. in breadth; the inner test is circular in outline, ·05 mm. in diameter, and it is connected with the outer test by numerous radial beams. Within the smaller test are several rods, which radiate from an excentric point to the margin. From the hedge-section at Lawell House, Chudleigh.

Genus LITHOCYCLIA, Ehrenberg.

Test discoid, with a lenticular latticed cortical shell connected by radial beams with a simple medullary shell surrounded by one or more concentric chambered equatorial rings, without radial appendages.

Lithocyclia devoniensis, sp. nov. Pl. XXVI. fig. 4. The test, as shown in section, is elliptical; the long diameter is ·23 mm., the lenticular shell is ·115 mm., and the central chamber ·065 mm. There are four rings; the inner one is somewhat wider than the others. The radial beams are only faintly shown. Ramshorn Down, Devon.

Genus TRIGONOCYCLIA, Haeckel.

Test discoid, with lenticular latticed cortical shell, simple medullary shell, and three solid radial spines on the margin of the disc.

Trigonocyclia? sp. *a*. Pl. XXVI. fig. 11. Test triangular in outline, two sides nearly straight, the third slightly curved, with long stout spines from the angles. Diameter of disc ·2 mm.; length of

spines ·25 mm. No structure is shown, and it is doubtful whether it rightly belongs to this genus. Not uncommon. Ramshorn Down.

Trigonocyclia? sp. *b*. Pl. XXVI. fig. 12. Test subtriangular in outline, the sides curved. Diameter of disc ·21 mm.; length of spines ·2 mm. No structure preserved. Ramshorn Down.

Genus Porodiscus, Haeckel.

Discoidea without phacoid shell; with a flat discoidal shell, in which a simple spherical central test is surrounded by concentric chambered rings (each ring divided by radial beams into imperfect chambers). Surface on the two flat sides covered by a porous sieve-plate; the margin simple.

Porodiscus lens, sp. nov. Pl. XXVII. fig. 10. As shown in section the test is elliptical, with a long diameter of ·14 mm. and transverse ·095 mm.; the central chamber is ·06 mm. in width. It has two rays diverging from an excentric point to its margin, and it is surrounded by two chambered rings, partitioned off by numerous rays. The surface-pores are not shown. Not uncommon. Hedge-section at Lawell House, Chudleigh.

Porodiscus brevis, sp. nov. Pl. XXVII. figs. 2, 3. Test elliptical to nearly circular in outline, diameter ·13 to ·15 mm.; central chamber relatively large, diameter ·08 mm. Within it are four beams radiating from an excentric point, and it is surrounded by one or two rings divided by radial beams. This form differs from the preceding in the larger size of the central chamber and the less development of the rings. Hedge-section at Lawell House, Chudleigh.

Porodiscus percinctus, sp. nov. Pl. XXVII. figs. 1, 11. Nearly circular in outline; diameter ·25 mm., with wide central chamber, ·08 mm. in diameter, surrounded by about seven concentric chambered rings of approximatively equal width. Radial beams numerous. The surface-pores not shown. Fig. 11 is a vertical section, probably of this species. Common at Ramshorn Down; in the hedge-section, Lawell House, near Chudleigh; and at Bishopsteignton.

Porodiscus sp. *a*. Pl. XXVII. fig. 13. This is a vertical section of a similar form to the preceding, but it is larger; the central chamber is ·09 mm. in width, and there are from seven to eight chambered rings. Ramshorn Down.

Porodiscus clathratus, sp. nov. Pl. XXVII. figs. 4, 12. The discoid test, of medium size, is ·18 mm. in diameter; the central chamber is ·06 mm. in width. It is surrounded by four concentric chambered rings; the innermost is wider than the others. The radial beams are numerous. In fig. 12 the outer porous test is shown. Not infrequent. Ramshorn Down.

Genus Amphibrachium, Haeckel.

Test consisting of a central chamber and two opposite chambered arms.

Amphibrachium, sp. *a*. Pl. XXVII. fig. 7. The test is ·25 mm. in length, the central chamber ·09 mm. in diameter; the arms are equal and of the same width throughout, their ends are rounded or truncate. Only the outlines of the form are shown. Not uncommon. Carzantic Quarry, near Launceston.

Amphibrachium, sp. *b*. Pl. XXVII. fig. 5. As seen in section the central chamber is oval, and the arms fusiform or elliptical in outline, with obtuse ends. Total length ·39 mm., length of central chamber ·1 mm., greatest width of the arms ·05 mm. Carzantic Quarry.

Genus Rhopalastrum, Haeckel.

The test consists of three chambered arms.

Rhopalastrum ingens, sp. nov. Pl. XXVII. fig. 6. As shown in section, the three arms are unequal; the longest is fusiform in outline, thickest in the middle portion, and gradually tapering to an obtuse end; its length is ·63 mm., and greatest width ·11 mm. The other two arms are even throughout; the longest measures ·56 by ·08 mm., and the other, which appears to be incomplete, is ·45 by ·095 mm. No structure has been preserved, but its form and proportions readily distinguish it from other species which have been described. Rare. Ramshorn Down.

Rhopalastrum clavatum, sp. nov. Pl. XXVII. fig. 9. The test is not inflated in the centre, and gives no indication of a central chamber; the arms are club-shaped and subequal. Length of each arm ·47 mm., greatest width ·1 mm. Traces of pores are shown. Ramshorn Down.

Rhopalastrum, sp. *a*. Pl. XXVII. fig. 8. Only two of the three arms remain in this specimen. The arms are club-shaped and rounded at the ends and subequal. Length ·53 mm., breadth ·17 mm. in the thickest parts. There is no central inflation. In general form this specimen resembles *R. Isselii*, Rüst, from the Lower Carboniferous of Sicily, but is much larger. Ramshorn Down.

Subclass NASSELLARIA, Haeckel.

Order CYRTOIDEA, Haeckel.

Genus Sethocapsa, Haeckel.

The latticed test is divided by a constriction into two chambers, and the aperture is covered by a latticed plate.

Sethocapsa, sp. *a*. Pl. XXVII. fig. 17. The lower chamber is nearly circular in outline, and ·13 mm. in diameter, the upper is represented by a subcylindrical extension, ·16 mm. in length by

·04 mm. in width. No structure is shown, and the form is placed here from its resemblance to specimens from the Swiss Jura, figured by Rüst ('Palæontographica,' vol. xxxi. 1885, p. 306, pl. xxxvi. figs. 15–18). From Carzantic Quarry, near Launceston.

Genus Lithostrobus, Haeckel.

The conical latticed test has three or more transverse constrictions and a horn-shaped extension at the summit.

Lithostrobus, sp. *a*. Pl. XXVII. fig. 16. The test is divided into four chambers, the summit has an obtuse curved horn, the last chamber is much larger than the others, and the aperture is oblique. Length ·23 mm., greatest width ·08 mm. Heddon Quarry, near Barnstaple.

Genus Lithocampe, Haeckel.

The conical, oval, or fusiform latticed test has the aperture contracted, and it is without a horn-shaped process at the summit.

Lithocampe, sp. *a*. Pl. XXVII. fig. 15. Test conical, the constrictions indicate eight chambers, gradually increasing in size; the summit chamber is rounded, and the basal one contracted. Length ·25 mm., greatest width of last chamber ·09 mm. Not infrequent. Ramshorn Down.

Genus Stichocapsa, Haeckel.

Test conical, without horn at the summit; the aperture of the last or basal chamber is closed by a latticed plate.

Stichocapsa, sp. *a*. Pl. XXVII. fig. 14. Test evenly conical, with nearly straight sides and curved base, the summit pointed; the number of chambers is not shown. Length ·28 mm., greatest width ·09 mm. Common. From Ramshorn Down.

The following is a list of the genera of radiolaria which have been recognized in the Lower Culm Measures of the different areas referred to in the paper :—

Order Beloidea.

Genus *Sphærozoum*.

Order Sphæroidea.

Genus *Cenosphæra*.
Carposphæra.
Thecosphæra.
Xiphosphæra.
Xiphostylus.
Dorysphæra.
Acanthosphæra.
Staurolonche.

Order Prunoidea.

Genus *Cenellipsis*.
Ellipsoxiphus.
Druppula.

Order Discoidea.

Genus *Theodiscus*.
Sethodiscus.
Lithocyclia.
Trigonocyclia.
Porodiscus.
Amphibrachium.
Rhopalastrum.

Order Cyrtoidea.

Genus *Sethocapsa*.
Lithostrobus.
Lithocampe.
Stichocapsa.

Of the 23 genera enumerated above, 21 have been previously determined from the Palæozoic formations of this country and the continent, the larger proportion—17 genera—from the Culm of Germany, Sicily, and Russia by Dr. Rüst. Of the other 2 genera, one (*Trigonocyclia*) has not previously been recognized below the Jurassic, and the other (*Sethodiscus*), although a very simple form, does not seem to have been hitherto met with in the fossil state.

VIII. Description of the other Fossils associated in the same Rocks with the Radiolaria.

The Radiolarian or Codden Hill Beds of the Lower Culm Measures have hitherto been considered as practically unfossiliferous, and indeed their distinctive characters have been attributed to metamorphism.[1] Prof. J. Phillips,[2] however, who appears to have himself very diligently searched these rocks, described and figured from them the following 5 species:—*Turbinolopsis pauciradialis*, Phill., *Leptæna mesoloba*, Phill., *Terebratula* (*Atrypa*) *insperata*, Phill., *Goniatites mixolobus*, Phill., and *Cyathocrinus distans*, Phill., this last being merely detached joints of crinoid-stems. The other fossils which Phillips described in the same work from his so-called 'Carbonaceous group'[3] did not come from the Radiolarian or Codden Hill rocks, but from the dark limestones and shales underlying them at Swimbridge, Venn, Bampton, etc., in North Devon, and at Truscott, Lew Trenchard, and other localities in Cornwall and South Devon. The fossils enumerated by Mr. Ussher, in his 'British Culm Measures,'[4] from the Basement Beds of the Culm do not appear to include any at all from the Radiolarian or Codden Hill Beds; those given are from beds at Waddon Barton and other places in the Chudleigh district discovered and determined by Dr. Henry Woodward and Mr. R. Etheridge, Jun., in the celebrated shales with trilobites, in which no radiolaria have as yet been met with, and which are probably at a slightly lower horizon than the Codden Hill Radiolarian Beds.

Certain thin beds, however, in the Radiolarian series at Codden Hill and its neighbourhood, and also west of the Taw river near Barnstaple, contain a fairly varied but scanty fauna in addition to the radiolaria, and in view of the importance of these fossils in determining the geological horizon of the radiolarian rocks, and since many of them have not hitherto been recorded from this country, we give below detailed references to them. These fossils do not seem to be generally distributed in the Radiolarian rocks; so far they have been met with only in limited thin bands of whitish or yellowish soft shaly or platy rock, in which radiolarian casts are also abundant. With hardly an exception the calcareous

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxv. (1879) pt. ii. p. 5; also T. M. Hall, 'Sketch Geol. Devon.,' (White's Gazetteer), 1878, p. 9, reprint.

[2] 'Palæozoic Fossils of Cornwall, etc.,' 1841.

[3] *Ibid.* pp. 189, 194.

[4] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) pp. 159–161.

structure of these fossils has been wholly removed, and they are now preserved as casts in the soft siliceous matrix; but the casts, as a rule, retain very sharp and distinct impressions of the different forms.

(*a*) Sponges.

The only remains of sponges found are microscopic fragments of the long needle-like spicules which form the anchoring-wisps of hexactinellid sponges, and an occasional cruciform spicule of the same group. The fragments are in the same condition of preservation as the radiolaria in the same beds; they are not very abundant, but have been recognized at Codden Hill, Hannaford, and Templeton near Barnstaple; at Hulverton, North Devon; Ramshorn Down, hedge-section at Lawell House, Winstow Cottage, near Chudleigh, and at Landlake near Launceston.

(*b*) Corals.

Pleurodictyum Dechenianum, Kayser. Pl. XXVIII. figs. 18, 18*a*, 18*b*.

1882. Jahrb. der königl. Preussisch. geol. Landesanst. f. 1881, p. 84, pl. iii. figs. 20, 21.

This form is at present known only from casts; it seems to have been hemispherical or semioval, the base flattened or slightly concave; the corallites are conical, either round or subprismatic in transverse section, and connected with each other by small rods (the solid infillings of the pores) disposed in vertical rows. There are from eight to ten rows in a single corallite. No traces of tabulæ or septal spines are present, nor is there any coiled tube as in *P. problematicum*.

The corallum is very diminutive; the base of a small specimen is only 5 mm., and the largest noted only 12 mm. across; the height of the coral appears to have been a little more than the basal width. The corallites range from 2 to 5 mm. in length, by ·7 to 2 mm. in width at the summit.

The forms are not infrequent in yellowish shales at Hannaford Quarry, near Barnstaple. Kayser's specimens were from the Culm kieselschiefer at Aprath, between Elberfeld and Wülfrath, Rhenish Prussia.

Cladochonus Michelini, M.-Edwards & Haime. Pl. XXVIII. figs. 19 & 19*a*.

1851. *Pyrgia Michelini*, M.-Ed. & Haime, 'Polyp. foss. Terrains paléoz.' p. 310, pl. xvii. fig. 8.
1872. *Cladochonus* ——, de Koninck, 'Nouv. Recherch. Anim. foss. terr. carbon. Belg.' p. 153, pl. xv. fig. 6.
1879. —— ——, Nicholson & Etheridge, Jun., Geol. Mag. p. 292.
1882. —— ——, Kayser, Jahrb. königl. Preuss. geol. Landesanst. f. 1881, p. 85, pl. iii. fig. 19.
1889. —— ——, Holzapfel, Pal. Abhandl. n. s. vol. i. (1889) p. 69.

The only example met with of this species is a very perfect cast of a single cup and pedicel, which together are 15 mm. in length. The pedicel is 10 mm. in length and 1 mm. in thickness near the

calice, but less in its lower portion; it is covered with concentric rugose striæ; the calice is slightly compressed, 5 mm. in width at the summit, and about the same in height. On the surface of the cast there are very regular vertical lines, about 20 in number, of delicate blunt spines or pustules, which would correspond to as many rows of minute holes in the actual calice, a feature which has not been noticed by previous authors, but in some of the specimens from the Carboniferous Limestone of Tournay, Belgium, now in the British (Nat. Hist.) Museum, there are within the calices rows of small holes instead of the usual septal striæ. From near the margin of the calice of our specimen the pedicel of another corallite is given off, and this is nearly completely separated from the parent form by a plaited septum. Our specimen is of similar size to those from the Tournay Limestone, but distinctly larger than that figured by Kayser from Aprath.

Distribution. In the yellowish shales at Hannaford, associated with *P. Dechenianum*. The only other locality in which it has been found in Britain is in the Lower Carboniferous Limestone series near Dunbar, whence it has been recorded by Nicholson and Etheridge, Jun. On the Continent this species has been found in the Culm shales of Aprath, Liebstein, and Kramberg, and in the Lower Carboniferous Limestone of Tournay.

Petraia, sp. Pl. XXVIII. figs. 20 & 20*a*.

Cf. *Petraia* (*Turbinolopsis*) *pauciradialis*, Phill., 'Pal. Foss. Cornwall, etc.' 1841, p. 5, pl. i. fig. 4.

Only the cast of the interior of the calice has been preserved; this is obliquely conical, truncate, 5 mm. in depth, 5·2 mm. wide at the summit, and 4·2 mm. at the bottom. The septa are 16 in number, and they have a distinct bilateral arrangement. A cardinal septum reaches nearly to the centre of the base of the calice, and there is a small depression at its free end. It has on each side a group of three septa. The alar septa connect with a low ridge which curves round the small central depression, and connected with this is the counterseptum and three other septa on each side of it. The septa appear to be narrow, with smooth, free margins. On both sides of each septum there is a row of minute holes—shown in the cast as small pustules—which are probably connected with the insertion of the mesenteric muscles.

In *P. pauciradialis*, Phill., there is a greater number of septa, and their margins are said to be denticulate.

From Hannaford Quarry, near Barnstaple.

(*c*) Crinoids.

Casts of detached joints of crinoidal stems, similar to those which Phillips provisionally named *Cyathocrinus distans* ('Pal. Foss.' 1841, p. 135, pl. lviii. fig. 49*), are fairly numerous in the same beds with the other fossils, but there is nothing in them to distinguish the particular genus to which they might belong.

(*d*) Trilobites. By Dr. Henry Woodward, F.R.S., P.G.S.

The intimate knowledge which Dr. Woodward possesses of Carboniferous trilobites, and especially of those from the Lower Culm Measures of Waddon Barton, near Chudleigh, South Devon, which he described in the Palæontological Society's volume for 1883–84, led us to seek his assistance in determining the forms from the Radiolarian Beds of North Devon, from which hitherto no trilobites have been recorded, and he has prepared the subjoined descriptions of them, for which we desire to express our sincere obligations to him.

Phillipsia Leei, H. Woodw. Pl. XXVIII. figs. 1 & 1*a*.

1883–84. 'Brit. Carbonif. Trilobites,' Pal. Soc. p. 66, pl. x. figs. 1, 2, 3, & 4.

This is a detached cheek of rather larger size than those obtained from the Culm of Waddon Barton, and it is interesting as showing the facets of the eye, which are not well seen in Mr. Lee's specimens; the surface is covered with fine, waving, anastomosing lines, of a different colour from the cheek. Also a conical glabella from the same bed.

Length of cheek 8 mm., breadth 4 mm.; the extremity of the cheek-spine is broken off. The glabella is 4 mm. in length by 2·5 mm. in breadth.

From the buff rottenstone with radiolaria at Hannaford Quarry, near Barnstaple. Collected by Mr. G. F. Tregelles. Also from the red shales of the Lower Culm at Waddon Barton, near Chudleigh, Devon.

Phillipsia minor, H. Woodw. Pl. XXVIII. fig. 2.

1883–84. 'Brit. Carbonif. Trilobites,' Pal. Soc. p. 68, pl. x. figs. 5, 6*a* & *b*, 7, & 8*a*.

This species is represented by two pygidia, both from Hannaford Quarry, the smaller one measuring 4 mm. in length by 4·5 mm. in breadth, and the larger 6 mm. in length by 7 mm. in breadth. The axis of the tail is elevated, and diminishes rapidly in size from before backwards; it is surrounded by a broad, smooth margin. There are about 12 segments on the axis; the pleuræ bifurcate.

This form also occurs in the Lower Culm of Waddon Barton.

Phillipsia Cliffordi, H. Woodw. Pl. XXVIII. figs. 3 & 3*a*.

1883–84. 'Brit. Carbonif. Trilobites,' Pal. Soc. p. 69, pl. x. figs. 8*b*, 9, 10, 11, & 12.

This species is represented by a head and tail of a small individual, the thoracic segments having been displaced or lying underneath. This specimen, together with the impression and counterpart of a small tail, come from Combe Wood quarry, Codden Hill, near Barnstaple.

An impression and counterpart of 5 thoracic segments attached to a pygidium comes from the soft radiolarian shales of Tawstock, near Barnstaple.

Also an impression and counterpart and two rilievo tails are before us from Hannaford Quarry.

None of these specimens call for special remark. They vary in size, but agree very well with *Ph. Cliffordi* from the Lower Culm of Waddon Barton.

Phillipsia ? (larval form). Pl. XXVIII. fig. 4.

This little specimen, which is represented by the impression and counterpart, exhibits the head-shield and pygidium with about 5 thoracic segments united together. The head-shield and pygidium are semicircular in outline, and the free cheeks are furnished with short spines projecting slightly outwards, as in *Ph. minor*.

The entire length of the specimen is 4·5 mm. and the greatest breadth 4 mm. The thorax measures 1·5 mm. in length, and the head and pygidium are each 1·5 mm. long.

This is probably a larval form, but it would be unsafe to hazard an opinion as to the species; possibly it may be *Ph. Cliffordi*: the pygidium has too round an outline for *Ph. minor*.

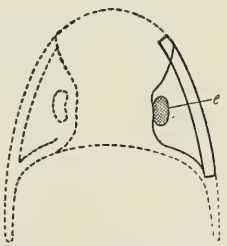
The specimen is in a white siliceous rock from Hannaford Quarry.

Griffithides acanthiceps, H. Woodw. Pl. XXVIII. figs. 5 & 5*a*.

1883–84. 'Brit. Carbonif. Trilobites,' Pal. Soc. p. 32, pl. vi. figs. 2, 10, & 11, and pl. vii. figs. 2 & 3.

This specimen seems to agree best with *Griffithides acanthiceps*; it consists of the free cheek of the right side only, of which the impression and counterpart are preserved in a pale yellow shale (resembling rottenstone in friability). The facets of the eye on the rilievo half, fig. 4 *e*, are exquisitely preserved, but only faintly to be detected upon the counterpart. Length of outer margin of head or cheek 18 mm., breadth of margin of cheek 2 mm., breadth of cheek 6 mm., length of eye 2·5 mm., breadth of eye 1·5 mm.

Fig. 4.



This species has hitherto been recorded only from the Carboniferous Limestone of Craco, near Grassington, Settle, Yorkshire, and Castleton, Derbyshire. We are now able to record it from the Lower Culm of Hannaford Quarry, near Barnstaple. Collected by Mr. G. F. Tregelles.

Griffithides longispinus, Portlock, 1843. Pl. XXVIII. fig. 6.

1843. Portlock, 'Geol. Rept. Lond.' p. 312, pl. xxiv. fig. 12.
1883–84. H. Woodward, 'Brit. Carbonif. Trilobites,' Pal. Soc. p. 36, pl. vii. figs. 5 *a*, *b*, *c*, & 6.

This specimen, which is one of the most complete from the radiolarian Culm of Codden Hill, has the head-shield, thoracic segments, and pygidium preserved together; they are, however, unfortunately decorticated, so that the ornamentation of the surface

cannot be discerned save in a few spots, and the intaglio side (which may have retained the external shelly crust) has not been preserved. The specimen measures 25 mm. in length and 12 mm. across the thoracic segments; the length from the front of the glabella to the point of the cheek-spine is 20 mm., the length of the cheek-spine itself being 8 mm., and its breadth where it joins the cheek 2 mm. The head is much broken up and squeezed back under the axis of the thorax, displaying more or less the first three thoracic segments which thus override the head; the six posterior thoracic segments remain undisturbed and in their normal position united to the pygidium. The pygidium is rather narrow and somewhat pointed, and it has a smooth border; the number of coalesced segments cannot be ascertained, as the subdivisions are obliterated, but its general form agrees very well with that of *Griffithides longispinus*.

In consequence of the squeezing in of the glabella, the cheek-spines with the free cheeks are pressed apart and bent outwards, giving the cheek-spines the appearance of diverging from the head at a wide angle on either side. The impression indicates that the spines were long, flat, and striated, which is Portlock's description of the spines in *G. longispinus*.

This species has hitherto been recorded only from the Carboniferous Limestone of Carnteel, Tyrone. At Codden Hill it occurs in a platy, grey, siliceous rock. Collected by Mr. J. G. Hamling, F.G.S., of Barnstaple.

Proetus, sp. *a*. Pl. XXVIII. figs. 7 & 7*a*.

This species is represented by a body consisting of nine thoracic segments and a pygidium, also by one detached pygidium; the latter retains the shelly covering, but the former is decorticated.

Breadth of thorax at anterior border 6 mm., at union with pygidium 5 mm., length of the 9 segments 3 mm., breadth of axis 2 mm. Breadth of axis of pygidium 2 mm., breadth of pygidium 4·5 mm., length 2 mm.

Detached pygidium: breadth 7 mm., length 3 mm., width of axis 3 mm.; this specimen shows from 6 to 7 coalesced segments in the axis and about 5 ribs on each lateral border; these ribs pass from the axis into the lateral border, and show a tendency to bifurcate near the margin. The specimen is in a white siliceous rock from Combe Wood Quarry, and that described in the previous paragraph comes from the Codden Hill Quarry, near Barnstaple. Collected by Mr. J. G. Hamling.

Proetus, sp. *b*. Pl. XXVIII. fig. 8.

This small trilobite agrees best with the genus *Proetus*; it is represented by an intaglio of the head with 5 to 6 segments of the thorax attached, and a pygidium with 3 thoracic rings joined to it, slightly separated from the rest of the specimen on the same surface of rock. The head-shield is imperfect; but one cheek shows the small eye, the raised margin of the lateral border, and the short

lateral spine. The ribs are rounded and separated by deep furrows; the axis is somewhat narrow; the pygidium seems to consist of from 6 to 7 coalesced segments, its axis is bluntly triangular, is marked on either side by a parallel groove, and does not extend to the posterior border. The ribs on the lateral border, which are 6 in number, die away leaving a smooth margin.

Breadth of head at the neck-furrow 6 mm., length 5 mm., breadth of cheek 2·5 mm. Length of five thoracic segments following the head 4·5 mm., breadth 5·5 mm. Pygidium with three thoracic segments united to it 5 mm.; pygidium alone, length 2·5 mm., breadth 4·5 mm., width of axis at tail 2 mm.

In white siliceous rock from the Combe Wood Quarry, near Barnstaple. Collected by Mr. J. G. Hamling.

(*e*) Brachiopoda. By F. A. Bather, Esq., M.A., F.G.S.

Mr. Bather has kindly examined for us the brachiopoda from the Radiolarian (Codden Hill) Beds, and has supplied us with the following notes on their identification:—

Discina nitida, Phillips, sp.

1836. *Orbicula nitida*, 'Geology of Yorkshire,' vol. ii. p. 221, pl. xi. figs. 10–13.
1857. *Discina nitida*, Davidson, 'Brit. Carbonif. Brachiop.' Pal. Soc. vol. ii. pt. v. p. 197, pl. xlviii. figs. 18–25, p. 268.
1874–82. —— ——, 'Brit. Carbonif. Brach. Suppl.' vol. iv. p. 268, pl. xxx. figs. 12 & 13.

A rather imperfect specimen, apparently of this species. At any rate it differs from the species of *Discina* described by Holzapfel from the Lower Carboniferous of Liebstein (Pal. Abhandlung. n. s. vol. i. 1889, p. 67) and from *Discina marginata*, Sandberger, which Sarres recorded from the Culm of Aprath. Length 12 mm., width 9 mm.

From Codden Hill Quarry (coll. J. G. Hamling). It is widely distributed also in the Carboniferous Limestone of Yorkshire, Scotland, Ireland, etc.

Productus plicatus, Sarres. Pl. XXVIII. figs. 10, 10 *a*, & 10 *b*.

1857. 'Inaugural Dissertation,' p. 20.
1882. Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 81, pl. iii. figs. 1 & 2.

The specimens are smaller and finer than those described by Sarres and Kayser, while the ears seem to project a little more. Spines are only shown in one specimen. Kayser compares the species with *P. Carringtonianus*, Davidson; but that is a larger, coarser, and more vaulted form. There is no other British species with which comparison is possible, but the *P. concentricus* of Sarres is clearly, as Kayser says, a very close ally. Length 5 mm., breadth 8 mm.

From Hannaford Quarry, near Barnstaple. Also from the Lower Culm at Aprath, Rhenish Prussia.

Productus concentricus, Sarres. Pl. XXVIII. figs. 9, 9 *a*, & 9 *b*.

1857. 'Inaugural Dissertation,' p. 21.
1882. Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 83, pl. iii. figs. 3 & 4.

The greater relative width of the shell and the well-marked sinus induce me to refer the specimens to this species rather than to *P. plicatus*. Possibly this is the *Leptæna mesoloba* (?), of Phillips ('Pal. Fossils, etc.' 1841, p. 61, pl. xxv. fig. 102). The specimens, in common with the others described, are only casts, and they are as a rule very diminutive. Length 2·7 mm., breadth 4 mm. One specimen is a specially wide form of the species; its length is 4·5 mm., and breadth 11·5 mm.

Not uncommon in Tower Hamlet Quarry and Hannaford Quarry, near Barnstaple. Also at Aprath in the Lower Culm.

Productus cf. *P. lævipunctatus*, Sarres. Pl. XXVIII. figs. 11 & 11*a*.

1857. *Productus lævipunctatus*, Sarres, 'Inaug. Dissert.' p. 21.
1882. —— ——, Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 80, pl. iii. fig. 5.

The specimen is an internal cast; it has a sinus on the ventral valve similar to that in the above species, but the shell is proportionately somewhat wider than in the specimen figured by Kayser. Length 3·25 mm., breadth 6 mm.

From Hannaford Quarry, near Barnstaple. Also from the Lower Culm at Aprath.

Chonetes rectispina, von Koenen? Pl. XXVIII. figs. 12, 12 *a*, & 12 *b*.

1879. Neues Jahrb. für Mineralogie, etc. p. 327, pl. vii. fig. 4.
1882. Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 78, pl. iii. figs. 13 & 14.

It is difficult to distinguish the specimens from some varieties of *Ch. hardrensis*, as understood by Davidson. Length 4·5 mm., breadth 6 mm.

Frequent in the soft yellowish shale at Overton Quarry and Hannaford Quarry, near Barnstaple. Also in the Lower Culm of Aprath and at Herborn.

Chonetes Laguessiana, de Koninck. Pl. XXVIII. figs. 13 & 13 *a*.

1843. 'Descript. des Anim. foss. du Terrain Carbonif. Belgique,' p. 211, pl. xii. bis, fig. 4 *a*, *b*.
1857. *Chonetes hardrensis*, Davidson, 'Brit. Carbonif. Brachiop.' Pal. Soc. vol. ii. pt. v. p. 186, pl. xlvii. figs. 12–16, 17, 18.
1874–82. —— *Laguessiana*, *ibid.* vol. iv. p. 312, pl. xxxiv. fig. 18.
1882. Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 77, pl. iii. figs. 17 & 18.

This differs from the specimens referred to *Ch. rectispina* in its greater relative breadth. Length 3 mm., breadth 5·2 mm.

From Hannaford Quarry, near Barnstaple, and from Westleigh (Rev. W. Downes). Also from the Lower Culm at Aprath (Kayser), and from the Carboniferous Limestone of Yorkshire, Shropshire, North of England, Scotland, Ireland, and Belgium.

Leptæna analoga, Phill. Pl. XXVIII. figs. 14 & 14 *a*.

1836. *Producta analoga*, Phill. 'Geol. Yorks.' vol. ii. p. 215, pl. vii. fig. 10.
1841. *Leptæna* ——, Phill. 'Pal. Foss. Cornw.' p. 56, pl. xxiv. fig. 93.
1857. *Strophomena rhomboidalis*, var. *analoga*, Davidson, Pal. Soc. Mon. "Carb. Brach." vol. ii. pt. v. p. 119, pl. xxviii. figs. 1, 2; Supplement, vol. iv. p. 291, pl. xxxvi. fig. 23.
1882. —— *analoga*, Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 77.

The specimen is rather smaller and finer than the usual forms of this species, agreeing in these respects with the other Culm brachiopoda. Length 4·5 mm., breadth 5·75 mm.

From Hannaford Quarry, near Barnstaple, also from the Lower Culm of Aprath. Phillips has figured it from the Devonian of Croyde Bay, North Devon, and Davidson states that it is common in the Carboniferous Limestone of Yorkshire, Derbyshire, Scotland, Ireland, and Belgium.

Orthotetes crenistria, Phillips, sp. Pl. XXVIII. figs. 15 & 15 *a*.

1836. *Spirifer crenistria*, Phill. 'Geol. Yorks.' vol. ii. p. 216, pl. ix. fig. 6.
1857. *Streptorhynchus* ——, Davidson, 'Brit. Carb. Brachiop.' Pal. Soc. vol. ii. pt. v. p. 124, pl. xxvi. figs. 1–6, pl. xxvii. figs. 1–7.
1874–82. —— ——, *ibid.* vol. iv. p. 288, pl. xxxvii. figs. 1–5.
1882. —— ——, Kayser, Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 77, pl. iii. fig. 12.

A specimen of the ventral or peduncle-valve and the internal cast, showing median septum and four muscle-scars. Common. Length 7·5 mm., breadth 6 mm. The specimens are small, but even smaller occur in the Lower Culm of Aprath.

From quarries at Hannaford and Codden Hill, near Barnstaple. It has a wide distribution in the Carboniferous Limestone of Yorkshire, Scotland, Ireland, Belgium, etc.

Spirifer, sp. Pl. XXVIII. figs. 16 & 16 *a*.

Two specimens of internal casts of the dorsal or brachial valve clearly belong to this genus, but are not sufficiently preserved to be referred to any species. They do not, however, appear to belong to any species hitherto described from the Culm or to any Carboniferous *Spirifer* figured by Davidson. The approximative proportions are:—height $\frac{2}{3}$ width; hinge $\frac{3}{4}$ width of shell. The brachial valve shows a wide median rib about $\frac{1}{4}$ width of shell. On either side are 4 or 5 radiating ribs, which gradually diminish in width. The area of the valve appears to have been fairly pronounced, and marked with horizontal and vertical striæ; its hinge-margin was crenulate. The interior shows a ribbed cardinal process and a fine median septum.

From Hannaford Quarry, near Barnstaple.

Athyris, sp. Pl. XXVIII. figs. 17 & 17 *a*.

In the absence of calcareous structures one cannot definitely say whether this specimen belongs to the looped *Dielasma* or to the spire-bearing *Athyris*, but on the whole the features that it possesses in common with *Athyris* seem of more importance than those which resemble *Dielasma*.

From Hannaford Quarry and Overton Quarry, near Barnstaple.

(*f*) Cephalopoda. By G. C. Crick, Esq., F.G.S.

For the subjoined notes on the Cephalopods we are indebted to Mr. G. C. Crick, of the Natural History Museum.

Among the specimens from the Radiolarian (Codden Hill) Beds I recognize the following Goniatites :—

1. *Goniatites* [*Prolecanites*] *mixolobus*, Phillips.
2. „ „ sp.
3. „ [*Nomismoceras*] *spirorbis*, Phillips.
4. „ [*Pericyclus*], sp.

1. *Goniatites* [*Prolecanites*] *mixolobus*, Phillips.

This species is represented by at least one specimen. It shows a portion of the suture-line and agrees with Phillips's type ('Geol. Yorksh.' vol. ii. pl. xx. fig. 43) from the Carboniferous Limestone of Bolland, Yorkshire, with which I have carefully compared it.

I have examined the specimen belonging to the Museum of Practical Geology, from the Lower Culm Measures of Westleigh, North-east Devon, which is marked as one of the specimens figured as *G. mixolobus* by Prof. Phillips in his 'Palæozoic Fossils of Cornwall, Devon, etc.' (pl. li. fig. 235; probably fig. 235*f*); but the fossil is so imperfectly preserved that I am unable to confirm this identification. There are, however, in the same Museum examples from Westleigh which I think are quite correctly referred to Phillips's *G. mixolobus*.

From Codden Hill Quarry, and Overton Quarry, near Barnstaple, and from Westleigh. It also occurs in the Lower Culm of Aprath and Herborn, and in the Carboniferous Limestone of Bolland, Yorkshire, and Visé, Belgium.

2. *Goniatites* [*Prolecanites*], sp.

In addition to the specimen referred to above there are several forms which belong to *Prolecanites*, but, since only fragments of their suture-lines can be made out, they are not specifically determinable. They may be crushed examples of *G.* (*Pr.*) *mixolobus*, but in their general character they approach closely *G.* (*Pr.*) *ceratitoides*, von Buch, as figured by Holzapfel (Pal. Abhandl. n. s. vol. i. pls. iii. & iv.) from the Lower Carboniferous of Erdbach-Breitscheid, near Herborn. The Jermyn Street Museum contains a similar specimen from Westleigh, North-east Devon.

From Codden Hill Quarry and Overton Quarry, near Barnstaple, and from Westleigh.

3. *Goniatites* [*Nomismoceras*] *spirorbis*, Phillips.

One specimen is clearly referable to this species, as identified by Phillips from Westleigh, North-east Devon, from which locality there is an example in the Museum of Practical Geology, Jermyn Street. These specimens do not show the suture-line, but they are most probably identical with the *G. spirorbis* which Phillips had

previously described from the Carboniferous Limestone of Bolland, Yorkshire.

From Beacon Quarry, Codden Hill, near Barnstaple, and from Westleigh. It also occurs in the Carboniferous Limestone of Visé, Belgium.

4. *Goniatites* [*Pericyclus*], sp.

A small goniatite, although specifically indeterminable, belongs to the section *Pericyclus*, a section which, so far as is known, is confined to the Lower Carboniferous. It appears to be near either *G.* [*Pericyclus*] *virgatus*, de Koninck, or *G.* [*Pericyclus*] *Hauchecornei*, Holzapfel, both figured by the latter author from the Lower Carboniferous of Erdbach-Breitscheid.

From the Overton Quarry, Codden Hill, near Barnstaple (coll. J. G. Hamling).

Table II. (p. 655) has in part been drawn up from the List of Fossils determined by Dr. Henry Woodward and Mr. R. Etheridge, Jun.,[1] from the Lower Culm shales of Waddon Barton, near Chudleigh, to which have been added the fossils from the limestones and shales of Canonsleigh and Westleigh, North-east Devon, obtained by the late Rev. W. Downes,[2] which appear to have been determined with some care. The cephalopoda in this list have been revised by Mr. G. C. Crick, and we are indebted to Mr. A. Smith Woodward[3] for the information respecting the two species of fishes from Instow.

We have omitted references to fossil plants in the above-mentioned list, for the reason that none are known to occur in the Radiolarian Beds, and it is doubtful whether any have been determined from the Lower Culm Measures as distinct from those in the Culm itself and shales immediately associated therewith, which may be said to belong to the Upper Culm Measures, with which we are not concerned in the present paper. Mr. R. Kidston, F.G.S. (quoted by Dr. Henry Woodward),[4] gives a list of 8 species of plants from the Culm, which have a Calciferous Sandstone facies and are equivalent to the Culm in Germany, but the precise horizon and locality whence these plants came are not stated, and it appears that one of the forms (and possibly others also) is from the Marwood Beds at Sloly quarry, near Barnstaple, which are regarded[5] as of Upper Devonian age. Prof. Phillips[6] has stated that plants occur in beds corresponding to the Codden Hill Series at Lew Trenchard and Truscott in the Launceston district, but it is doubtful whether these plant-bearing beds are really the equivalents of the Radiolarian rocks.

[1] 'Brit. Carbonif. Trilobites,' Pal. Soc. 1883–84, p. 64.
[2] Trans. Devon. Assoc. vol. x. (1878) p. 331.
[3] Catalogue Foss. Fishes Brit. Mus. pt. ii. (1891) pp. 403, 490.
[4] 'Brit. Carb. Trilob.' p. 59.
[5] T. M. Hall, 'Sketch Geol. Devonsh.' 1878, repr. p. 6.
[6] 'Pal. Foss. Cornwall, etc.' 1841, p. 195.

TABLE I.—LIST OF THE FOSSILS (EXCLUDING RADIOLARIA) from the RADIOLARIAN (CODDEN HILL) BEDS referred to above, showing THEIR DISTRIBUTION in other parts of the Culm Series and in the Carboniferous Limestone of other localities.

	LOWER CULM SERIES.					CARBONIFEROUS LIMESTONE.			
	Dark Limestones and Shales of Venn, Swimbridge, Bampton, and Fremington, N.Devon.	Limestones and Shales of Canonsleigh and Westleigh, N.E. Devon.	Shales of Bampton, N. Devon, and Waddon Barton, S.E. Devon.	Nodular Shales of Instow, N. Devon.	Germany, Aprath, Herborn.	Yorkshire, and N. of England.	Scotland.	Ireland.	Belgium.
1. Spicules of Hexactinellid Sponges									
2. *Pleurodictyum Dechenianum*, Kayser	...	...	...	...	*				
3. *Cladochonus Michelini*, M.-E. & H.	...	...	...	...	*	...	*	...	*
4. *Petraia*, sp., cf. *P. pauciradialis*, Phill.									
5. Crinoidal stems = *Cyathocrinus distans*, Phill.	...	*							
6. *Phillipsia Leei*, H. Woodw.	...	...	*						
7. *Phillipsia minor*, H. Woodw.	...	...	*						
8. *Phillipsia Cliffordi*, H. Woodw.	...	...	*						
9. *Phillipsia*, sp.									
10. *Griffithides acanthiceps*, H. Woodw.	...	...	...	...	...	*			
11. *Griffithides longispinus*, Portl.	...	...	...	...	...	...	...	*	
12. *Proetus*, sp.									
13. *Proetus*, sp.									
14. *Discina nitida*, Phill. sp.	...	...	...	...	..	*	*	*	
15. *Productus plicatus*, Sarres	...	...	...	...	*				
16. *Productus concentricus*, Sarres	...	...	...	...	*				
17. *Productus lævipunctatus*, Sarres	...	...	...	...	*				
18. *Chonetes rectispina*, v. Koenen	...	...	*	...	*				
19. *Chonetes Laguessiana*, de Kon.	...	*	...	...	*	*	*	*	*
20. *Leptæna analoga*, Phill.	...	...	...	...	*	*	*	*	*
21. *Orthotetes crenistria*, Phill., sp.	...	...	...	...	*	*	*	*	*
22. *Spirifer*, sp.									
23. *Athyris*, sp.									
24. *Goniatites* [*Prolecanites*] *mixolobus*, Phill.	...	*	...	...	*	*	...	...	*
25. *Goniatites* [*Prolecanites*], sp.									
26. *Goniatites* [*Nomismoceras*] *spirorbis*, Phill.	...	*	...	...	...	...	...	...	*
27. *Goniatites* [*Pericyclus*], sp.									

TABLE II.—LIST OF OTHER FOSSILS from the Lower Culm Measures of the S.W. of England NOT KNOWN TO OCCUR IN THE RADIOLARIAN (CODDEN HILL) BEDS, and THEIR DISTRIBUTION in the Culm and in the Carboniferous Limestone of other localities.

	Lower Culm Series.					Carboniferous Limestone.			
	Dark Limestones and Shales of Venn, Swimbridge, Bampton, and Fremington, N.Devon.	Limestones and Shales of Canonsleigh and Westleigh, N.E. Devon.	Shales of Bampton, N. Devon, and Waddon Barton, S.E. Devon.	Nodular Shales of Instow, N. Devon.	Germany, Aprath, Herborn.	Yorkshire and N. of England.	Scotland.	Ireland.	Belgium.
Endothyra, sp.	...	*							
Michelinia favosa, Goldf.	...	*	...	...	...	...	...	*	*
Zaphrentis cylindrica (?), Scouler	...	*	...	...	...	...	...	*	*
Phillipsia articulosa, H. Woodw.	...	...	*						
Fenestella, sp.	...	...	*						
Spirifer, sp.	...	*							
Spirifer Urii, Fleming	...	...	*	...	...	*	*	*	
Orthis Michelini, Davids.	...	*	...	...	...	*	*	*	*
Chonetes deflexa, v. Koenen	...	...	*	...	*				
Avicula lepida, Goldf.	...	...	*	...	*				
Pteronites, sp.	...	...	*						
Pteronites, sp.	...	...	*						
Pecten, sp.	...	...	*						
Posidonomya corrugata, Eth.	...	...	*						
Posidonomya Becheri, Bronn	*	*	*	...	*	...	...	...	*
Posidonomya tuberculata, Sow.	*								
Posidonomya lateralis, Sow.	*	*							
Goniatites [*Glyphioceras*] *sphæricus*, Mart.	*	...	...	...	*	*	*	*	*
Goniatites [*Glyphioceras*] *spiralis*, Phill.	...	...	*						
Goniatites [*Glyphioceras*] *crenistria*, Phill.	*	...	...	...	*				
Goniatites [*Glyphioceras*] *striatus*, Sow.	*	...	...	...	*	*	...	...	*
Goniatites [*Glyphioceras*] *Listeri*	...	...	...	*	...	*			
Orthoceras cylindraceum, Sow.	*								
Orthoceras striolatum, Sandb.	...	...	*	...	*				
Cœlacanthus elegans, Newberry	...	...	...	*					
Elonichthys Aitkeni, Traquair	...	...	...	*					

IX. Position of the Radiolarian (Codden Hill) Beds in the Lower Culm Series.

It has been already mentioned that De la Beche states very distinctly that in North Devon there is no evidence of unconformity between the Devonian and Carboniferous or Culm Measures, but that there is a gradual passage from the shales and slates of the Upper Devonian rocks into black carbonaceous shales and limestones with an abundance of *Posidonomyæ*. These black beds have been generally regarded as the lowest fossiliferous beds of the Culm Measures, both in North and South Devon and in Cornwall. They contain but few species of fossils; as shown in the List given above, there appear at present to be but 7 species known in them, namely 3 species of *Posidonomya*, including *P. Becheri*, *Goniatites sphœricus*, Mart., *G. crenistria*, Phill., *G. striatus*, Sow., and *Orthoceras cylindraceum*, and none of these forms has as yet been met with in the Radiolarian (Codden Hill) Beds. These dark *Posidonomya*-limestones and shales are shown more particularly near Fremington, and at Venn and Swimbridge, near Barnstaple, also at Bampton in North Devon and near Wooladon, Lifton, etc., in the Launceston district. We think that there is sufficient evidence for the view that these rocks occupy a lower position in the series than the Radiolarian (Codden Hill) Beds. As already mentioned, we have ourselves observed in the Wooladon quarries near Launceston a clear upward succession from the dark limestones and shales containing *Posidonomya* into cherty rocks containing radiolaria, which appear to be the lower beds of the Radiolarian Series. Mr. Ussher, on the other hand,[1] gives no decided opinion as to the order of succession in the Lower or Basement Culm Measures, but while admitting that Phillips might be correct in placing the Codden Hill Beds above the dark shales and limestones, he thinks it best, as the lithological characteristics are not permanent but recurrent on the same or nearly the same horizons, to group the Basement Beds in one series rather than subdivide them.

Probably next in the upward order of succession to the *Posidonomya*-limestones and shales are the bluish-brown and reddish shales of Waddon Barton, near Chudleigh, and adjoining localities in the Bovey Tracey district in South-east Devon; near Bampton in North Devon; and, according to Mr. Ussher,[2] in some localities south of Launceston. These shales do not seem to be always developed above the dark *Posidonomya*-limestones and shales, and in some localities they appear rather to take the place of the latter. They possess a very distinct fauna, the principal feature of which is the great abundance of *Goniatites spiralis*, Phill., of which some thin layers of the shale are almost entirely composed. The only

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) pp. 120, 121.
[2] *Ibid.* p. 132.

other cephalopod[1] is *Orthoceras striolatum*, Sandb., a species also occurring in the Lower Culm of Germany. Besides these, there are four species of *Phillipsia*, three of which also pass up into the Codden Hill Radiolarian Beds; three species of brachiopods, one of which is found in the Codden Hill Beds; and several species of lamellibranchs, including *Posidonomya Becheri*, the only form in common with the dark limestones and shales below. The presence of the trilobites shows that these *Goniatites spiralis*-shales are more nearly related to the Radiolarian Beds than to the underlying *Posidonomya*-beds.

As possible equivalents of the dark *Posidonomya*-limestones and shales of Venn, Swimbridge, etc., De la Beche considered[2] the massive bluish limestones with intercalated cherty beds and associated reddish shales which form the conspicuous ridges of Westleigh, Canonsleigh, and Holcombe Rogus in North-east Devon. They are very different in appearance from the *Posidonomya*-rocks and resemble in general characters the ordinary types of Carboniferous Limestone, so that they might almost be regarded as a local development of this rock, which comes in here between the Devonian and the Culm Measures in much the same way as in the Rhine Province near Düsseldorf referred to by Dr. Kayser.[3] In addition to foraminifera and species of corals and brachiopods which also occur in the Carboniferous Limestone, these beds likewise contain two species of cephalopods: *Goniatites mixolobus*, Phill., and *G. spirorbis*, Phill., which are present as well in the Codden Hill Radiolarian Beds, and the cherty portions of the beds also show casts of radiolaria. The only species common to these limestones and the dark *Posidonomya*-beds to the westward are *P. Becheri* and *P. lateralis*, Sow.

The Radiolarian (Codden Hill) Beds are next higher in the series, but their junction with the beds below has been seldom observed. At Wooladon, near Launceston, they rest upon the *Posidonomya*-beds; in other parts of this and the Tavistock district Mr. Ussher[4] states that below them are beds with *Goniatites spiralis*. At Ramshorn Down the same author[5] considers that they are at the base of the Culm and even below the *Posidonomya*-beds, but definite junctions are not exposed. Excluding the radiolaria, 25 species have been recognized in these beds, a greater number than in any of the other divisions. Only 7 of these occur in the other divisions of the Culm Series in this country, while 8 are known as well from the Lower Culm of Aprath and Herborn in Germany, and a similar number are likewise present in the Carboniferous Limestone of the British Islands and Belgium. The distinguishing features of the

[1] We have been unable to verify the occurrence in these beds of *Goniatites mixolobus* and *G. sphæricus* as stated in 'Mon. Carb. Trilobites,' Pal. Soc. 1883-84, p. 64.

[2] 'Report Geol. Cornwall, etc.' 1839, p. 105.

[3] Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 52.

[4] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 129.

[5] *Ibid.* p. 134.

fauna of this division (excluding the radiolaria) are the number of the species of trilobites, of which 8 have been recognized by Dr. Woodward, and the numerous diminutive brachiopods, mainly of the genera *Productus*, *Chonetes*, and *Orthotetes*. Crinoids also must have been abundant, judging by the number of the casts of the stem-joints. Corals are few in number, and they are markedly small types. The cephalopods include *Goniatites mixolobus*, Phill., *G. spirorbis*, Phill., and two other undetermined species. The Radiolarian Beds are probably continuous round the margin of the Culm Measures, but for the most part only the microscopic organisms are recognizable in them—the larger fossils being known only from some thin shaly layers in the Barnstaple district.

It is only at Beeny Cliff, near Boscastle, and in the section in the town of Tavistock that we have observed the beds above the Radiolarian (Codden Hill) rocks, and in these localities they pass up conformably into fine dark shales in which no fossils were observed. According to Mr. Ussher,[1] the Codden Hill Beds of Lifton Wood, near Launceston, are overlain by yellowish-brown conglomeratic beds, those at Ugbrooke Park[2] and near Oldchard, in the Chudleigh district, by coarse, partially conglomeratic sandstones, and those at Ramshorn Down[3] by sandstones and shales with traces of plants. It is hardly probable that the Radiolarian Beds are directly succeeded by beds of coarse clastic materials, and the fact that the Ugbrooke Park conglomerates contain fragments of dark cherty rock similar to the Radiolarian Beds below suggests, as Mr. Ussher remarks, a prior denudation of the lower rocks.

Distinctly higher in the Culm Measures than the Radiolarian Beds are some dark nodular shales near Instow in North Devon. These contain *Goniatites Listeri*, Mart., a fossil which also occurs in the Carboniferous Limestone; and two species of fishes which elsewhere are found in the Millstone Grit and Coal Measures. Mr. T. M. Hall[4] places these beds on the horizon of the Millstone Grit; but it remains to be determined whether these beds really belong to that horizon.

X. Correlation of the Radiolarian Beds.

The rocks most nearly related to the Radiolarian Beds and the associated strata of the Lower Culm Measures in the South-west of England are to be found in the Culm Series of Westphalia, Nassau, and the Harz. In the first-named region, at Aprath, between Elberfeld and Wülfrath, Dr. E. Kayser[5] states that the Culm beneath the Flötzleerer Sandstein, or Millstone Grit, consists of alum shales, *Posidonia*-shales, kieselschiefer, and limestone, and beneath this latter is the Carboniferous Limestone, at first only slightly developed below the Culm, but gradually increasing in

[1] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 128.
[2] *Ibid.* p. 140. [3] *Ibid.* pp. 134, 144.
[4] 'Sketch Geol. Devonsh.' 1878, repr. p. 10.
[5] Jahrb. d. königl. Preuss. geol. Landesanst. f. 1881, p. 53.

thickness until on the left side of the Rhine near Aix-la-Chapelle it replaces the Culm Beds altogether. Of the 29 species of fossils recorded by Dr. Kayser from the Culm of Aprath, 11 are found in our Culm Series, and 9 of these in the Radiolarian Beds. The correspondence is further shown by the occurrence at Aprath of 5 species of *Phillipsia* which are nearly related to the forms of this genus in the Radiolarian Beds of North Devon. So far as we are aware, no radiolaria have as yet been described from the Kieselschiefer of Aprath.

Dr. Holzapfel states [1] that the Culm Beds at Herborn in Nassau consist of Thonschiefer with *Posidonomya Becheri*, below which is a thin zone of Kieselschiefer resting on diabase, and this in some places is succeeded by black or dark limestones with *P. Becheri*. Holzapfel considers that the *Posidonomya*-shales are in character nearer to the Devonian than to the Carboniferous Limestone, especially in the abundance of cephalopods and the rarity of corals and brachiopods, and that they indicate a deep-water formation. Dr. von Koenen [2] has described 44 species of fossils from the Herborn Culm, but there are only 7 identical with the English beds.

The Culm Series in the Upper Harz is shown by A. von Groddeck [3] to consist of an upper series of conglomerates, shales, and grauwacke, known as the Grunder Grauwacke and the Clausthaler Grauwacke; below these are beds of Thonschiefer with *Posidonomya Becheri* and *Goniatites crenistria*, which rest on basal beds of Kieselschiefer.[4]

From this lowest division of the Culm near Clausthal, Lautenthal, and Lerbach, in the Upper Harz, in beds of adinole, wetzschiefer, and kieselschiefer, or lydite, Dr. Rüst [5] has described a large number of radiolaria, showing that, like the Culm Radiolarian Beds in this country, these rocks are mainly composed of siliceous organisms. So far as comparison is possible the forms from the Harz mostly belong to the same genera, and probably many are specifically identical with those in the corresponding beds in this country. Dr. Rüst further mentions [6] that dark carbonaceous beds of kieselschiefer and lydite from the Culm of Hesse, Waldeck, Russia, and Sicily often consist almost entirely of the shells and spines of radiolaria, with occasionally some sponge-spicules.

The Culm Measures farther east in Germany—in Thuringia; between Zwickau and Dresden in Saxony; in Silesia; and in Moravia—consist principally of conglomerates, sandstones, and

[1] Pal. Abhandl. n. s. vol. i. (1889) p. 3.

[2] Neues Jahrb. für Mineralogie, etc. 1879, pp. 309–346, & pls. vi.–vii. The list is quoted by Dr. Woodward in 'Carb. Trilobites,' Pal. Soc. 1883–84, p. 63.

[3] Jahrb. d. königl. Preuss. geol. Landesanst. f. 1882, pp. 44–67. See also Ussher, Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 171.

[4] Mr. H. M. Cadell states that the Kieselschiefer, which in the Upper Harz rests conformably on the Upper Devonian, is 100 feet in thickness—this includes the Adinole, Wetzschiefer, Grauwacke, and some lenticular limestones. The thickness of the Posidonomyenschiefer and Culm Limestone which rests above the Kieselschiefer of the same region is placed at 425 feet. See Proc. Roy. Phys. Soc. Edinb. vol. viii. (1884) p. 216.

[5] 'Palæontographica,' vol. xxxviii. (1892) pp. 111, 112. [6] *Ibid.* p. 122.

shales. They thus present more points of comparison with the Upper than with the Lower Culm of this country. In these regions the siliceous or Kieselschiefer beds of the Lower Culm are either not developed or they have been denuded away, since fragments of them are not infrequently found in the conglomerates. At Wildenfels in Saxony,[1] moderately thick limestones occur in the Lower Culm, which contain *Endothyra* and corals common to the Carboniferous Limestone, similarly to the limestones at Canonsleigh, etc., in North Devon.

There are no rocks elsewhere in the British Isles which show any close relationship to the radiolarian cherty and shaly beds of the Lower Culm Measures. Siliceous organic rocks[2] of considerable thickness do indeed occur in the Yoredale series of the Carboniferous, in Yorkshire, Lancashire, North Wales, and Ireland, and some of them have been compared by Prof. Phillips, with the cherts of Codden Hill; but microscopic examination shows that they are composed of sponge-remains, and no radiolaria have as yet been recognized in them.

The macroscopic fossils which occur in the Radiolarian (Codden Hill) Beds are either identical with or closely similar to species found in the Carboniferous Limestone of Yorkshire, Scotland, Ireland, and Belgium; many of them are present in the Lower Culm Beds of Germany, and they indicate that these radiolarian beds represent the Carboniferous Limestones of other portions of the British Isles.

The relationship of the Waddon Barton Beds with trilobites and *Goniatites spiralis*, and the dark *Posidonomya*-shales and limestones of Devon, etc., to the Lower Carboniferous (or Culm) of Westphalia and the Harz was pointed out some years since by Dr. Henry Woodward[3]; that of the Radiolarian Beds of Codden Hill to the Kieselschiefer with radiolaria of the same districts is of a still closer character.

XI. Summary and Conclusions.

The main fact brought out in this paper is the presence of a series of organic siliceous rocks, some of a very hard, cherty character, others platy, and yet others soft, incoherent shales, which are developed in the lower portion of the Culm Measures of Devon, Cornwall, and West Somerset. These rocks can be traced along, and a short distance within, the line of the boundary between the Upper Devonian slates and shales and the conformably succeeding Culm shales from a few miles west of Barnstaple, North Devon, to Ashbrittle, near Wellington in West Somerset, where the Culm Measures disappear beneath the New Red rocks. On the southern margin of the synclinal trough of the Culm Measures the same rocks are shown from near Boscastle, on the coast, up to and beyond

[1] K. Dalmer, Zeitschr. d. Deutsch. geol. Gesellsch. vol. xxxvi. (1884) p. 379.
[2] 'Brit. Pal. Sponges,' Pal. Soc. vol. for 1887, pp. 98–103; Geol. Mag. 1887, pp. 435–446.
[3] 'Brit. Carb. Trilobites,' Pal. Soc. 1883–84, p. 63.

Launceston, Cornwall; at Tavistock, and as far south as Painter's Cross, near St. Mellion, Cornwall, where a small outlier is exposed. On the east of Dartmoor they are shown at Ramshorn Down, near Bovey Tracey, also near Chudleigh, and at Bishopsteignton. These rocks, throughout, are characterized by radiolaria, occasionally associated with sponge-spicules. These organisms in some instances are thickly crowded in the beds, in other cases they are sparsely scattered in a siliceous groundmass. Detrital materials are, as a rule, absent in the Radiolarian Beds, but in some instances they occur as microscopically minute fragments of mica and quartz. Dark carbonaceous and ferrous materials, crystals of pyrites, and rhombohedral crystals or negative crystals of carbonate of lime or dolomite are also abundant in these rocks.

The radiolaria occur both in the hard, cherty beds and in the soft, friable shales; they are not well preserved, and are now mostly in the condition of siliceous casts. Forms belonging to 23 genera have been recognized; they are included in the following orders:— Beloidea, Sphæroidea, Prunoidea, and Discoidea. In addition to the radiolaria, a scanty but significant fauna of corals, trilobites, brachiopods, and goniatites is present in some limited thin shaly beds in the Barnstaple district. Nearly all the forms are diminutive; of the 23 species which have been determined, several are only known elsewhere from the Lower Culm of Germany, others are common to the Carboniferous Limestone of the British Isles and Belgium. From the other divisions of the Lower Culm Measures below the radiolarian rocks about 36 species are known, and 8 of these occur in the Radiolarian Beds.

No definite thickness can as yet be assigned to these beds. In common with the other strata of the Lower Culm they have been considerably disturbed, and continuous sections showing their relations to the other beds of the series are rarely shown. That they are of no inconsiderable thickness is proved by sections in quarries where a series of beds from 50 to 190 feet in vertical thickness are exposed.

Radiolarian deposits of a similar character to these fossil-beds are now known only from great oceanic depths, and we are justified in regarding these Culm radiolarian rocks as laid down in the deep water of an open sea at some distance from a shore-line. Such a conclusion must needs very considerably modify the current ideas as to the character and origin of the Culm Measures in the South-west of England, which have been regarded as a continuous series mainly of detrital deposits of shallow-water origin. Thus we find them described in recent text-books as a thick series of well-bedded grits, sandstones, and occasionally thin limestones, which pass down conformably into Upper Devonian strata and contain plants resembling those in the Calciferous Sandstone Series in Scotland, as well as animal-remains which point to a position low down in the Carboniferous system.

The facts now ascertained as to the real nature of the Lower Culm Measures show that the series of rocks included under the general

term of Culm Measures, instead of being, as at present supposed, an uniform series of shallow-water detrital deposits, really consist of two groups of rocks, which in their nature and origin present the widest possible differences. In the Lower Culm Measures, the basal *Posidonomya*-beds and the Waddon Barton Beds with *Goniatites spiralis* consist of fine shales and occasional thin limestones which may have been formed in a moderately deep sea, but not beyond the reach of the finer sediments brought from the land; and overlying these are the Radiolarian Beds, mainly made up of these organisms, and formed by the gradual accumulation of their remains in a deeper sea too far removed from a land-surface for any but the finest detrital particles to be carried out and mingled with them.

In the Upper Culm Measures, on the other hand, which are of great thickness and extend over the greater part of the Culm area, the beds consist of conglomerates, grits, sandstones, and shales, with occasional thin bands of the Culm itself and plant-remains, which show with sufficient clearness that this Upper Division has been formed under shallow-water conditions.

We are at present quite in the dark as to the nature of the changes which set in after the deposition of the Radiolarian Beds; the conglomerates overlying these latter in certain areas give evidence of an elevation and partial denudation of the Radiolarian Beds at an early period in the history of the Upper Culm Measures.

The additional fossils (excluding radiolaria) which we have found in the Radiolarian Beds tend to confirm the view that these and the Lower *Posidonomya*- and Waddon Barton Beds are the representatives and equivalents of the Carboniferous Limestone in other portions of the British Isles; not, however, in the at present generally understood sense that they are a shallow-water facies of the presumed deeper-water Carboniferous Limestones, but altogether the reverse, that they are the deep-water representatives of the shallower-formed calcareous deposits to the north of them. Regarded in this light, the occurrence of these Lower Culm Measures in Devon and Cornwall, within about 30 miles of the great development of Carboniferous Limestone in the Mendips to the north-west, no longer presents such an anomaly as seemed to be the case when they were believed to be of shallow-water formation. Under this impression as to their character, Mr. A. J. Jukes-Browne [1] considers that they indicate a muddy sea which received the sediments brought down by large rivers draining continental land, which probably existed south-west of these areas, and the shore-line lay not very far south of Devonshire. The picture, however, that we can now draw of this period is that while the massive deposits of the Carboniferous Limestone—formed of the skeletons of calcareous organisms—were in process of growth in the seas to the north, there existed to the south-west a deeper ocean in which siliceous organisms predominated and formed these siliceous radiolarian

[1] 'Building of the British Isles,' 2nd ed. 1892, p. 139.

rocks. These are of much less thickness than the equivalent Carboniferous Limestones, but this may arise from the fact that the siliceous organic deposits are of far slower accumulation than calcareous beds, and they may well have occupied in their formation an interval of time as great as that taken by the formation of the limestones.

It is worthy of note that the deep-sea character of the Lower Culm of Germany, which corresponds with our Lower Culm Measures, had been maintained by Dr. Holzapfel,[1] even before the discovery of radiolaria in the beds of Kieselschiefer furnished such strong evidence in support of this view.

Much field-work has to be done before a satisfactory knowledge of the 'British Culm Measures' can be obtained, and the present paper only professes to be an introduction to the study of the one division of the Radiolarian Beds. The Upper Culm Measures, which in our opinion should include the beds above the Radiolarian rocks (with perhaps the exception of the shales with fishes and goniatites at Instow), have only incidentally been considered, and the question of their relative age can be determined only by their plant-remains. We have, further, not referred to the igneous rocks which in Central Devon and Cornwall are of not infrequent occurrence in the Lower Culm Measures.

Postscript.

[Since this paper was read, one of us has examined the Lower Culm area to the north of the granite of Dartmoor, between Bridestow and Drewsteignton, in order to ascertain if the Radiolarian rocks could be also recognized in this district. The rock-exposures are mainly limited to the quarries, now for the most part disused, which have been worked for the Culm limestones. The following is a brief notice of the different exposures, beginning at Bridestow and from thence to the north-east:—

Bridestow.—In the large disused limestone-quarry about half a mile S.W. of the village there are angular masses of chert remaining on the refuse-heaps, and at the S.W. end of the quarry chert is shown in position associated with grey shale. The chert is dark, and traversed throughout with thin quartz-veins; microscopic sections show in it traces of radiolarian casts and also numerous rhombohedral crystals.

Sourton.—In the limestone-quarry about half a mile east of Bridestow village, a clear vertical section of more than 100 yards in length is exposed. The beds at the top consist of chert interbedded with dark siliceous shales; below these are impure limestones and shales, and, near the base of the section, dark limestones and shales. The prevailing dip is N.N.W.; the upper beds are much folded. The chert of the uppermost beds is partly dark and partly of a bluish tint; a microscopic section of the dark variety showed

[1] Palæont. Abhandl. n. s. vol. i. (1889) p. 6; see also 'Text-book of Comp. Geol.' Kayser-Lake, 1893, p. 126.

some bands crowded with radiolaria, with intermediate bands of siliceous shale. The limestone in this quarry is seen in thin section to be largely crystalline, with a few traces of organisms.

At *Sourton Down*, about a mile N.E. of the quarry just mentioned, there are two small quarries of chert on the crest of the hill, and the summit of the hill appears mainly to consist of chert. The beds are much folded and contorted; a thickness of 10–12 feet is shown. The chert is laminated, bluish, weathering grey, and traversed in all directions by fine quartz-veins. Radiolarian casts may be distinguished in it both with a lens and under the microscope.

On the south side of the Higher Collaven railway-bridge, about half a mile east of the Sourton quarry, there are layers of dark chert interbanded with dark and blue flinty rock, probably shale altered by contact with igneous rock (greenstone?) which here comes in. Microscopic sections of the chert show numerous radiolarian casts, which are infilled with cryptocrystalline silica.

Okehampton.—In the railway-cutting on the eastern side of the Meldon[1] viaduct of the L. & S.W. Railway, between two and three miles from Okehampton, a section, about 25 feet in height, of beds dipping N.N.W. is exposed. The rock is principally a black, compact chert, associated with dark, indurated shales. The chert contains radiolaria.

In the railway-cutting about one mile west of the Meldon viaduct, banded dark- and light-bluish flinty rocks, resembling porcellanized shale, are exposed near the band of igneous rock, in the same manner as at the Higher Collaven bridge. Mr. Ussher[2] has noticed these beds as belonging to the Basement Culm series. It may be mentioned that the dark chert is used for ballast on the railway in this district, and the radiolaria in it can be readily distinguished with a lens.

At the quarry by the public road at the south-western end of Okehampton, beds of limestone alternating with shales are shown, which dip N.N.W. at an angle of 55°. About 300 yards north of this quarry, on the western side of Church Hill, there are thick beds of black chert and shale; the chert has numerous quartz-veins; no radiolaria can be seen in it.

About 4 miles east of Okehampton are the extensive Lower Culm Limestone quarries of *South Tawton*. In the lower part of the quarry at present worked, about 60 feet of dark limestone with shales are exposed. The succession is best seen at the disused quarry, now full of water, nearest the village, where the limestone is seen to be overlain by dark carbonaceous shales, succeeded by pale-grey and buff soft shales, and at the summit by beds of chert and shale which form conspicuous prominences. The chert is compact, bluish, and thickly traversed by veins of quartz; in a microscopic section numerous casts of radiolaria are shown.

Drewsteignton.—At the large limestone-quarries close to this village, a section of about 80 feet in thickness is at present exposed.

[1] 'Elmdon' on the 1-inch Geol. Surv. map.

[2] Proc. Som. Archæol. & Nat. Hist. Soc. vol. xxxviii. (1892) p. 136.

The beds are mainly of limestone and shales in the lower portion of the quarry; above these, beds of cherty rock several feet in thickness are interbedded with limestone. A microscopic section of the chert showed radiolarian casts in places. According to the late Mr. G. W. Ormerod,[1] *Posidonomya* occurs in one of the lower beds of limestone in this quarry.

Judging by the above-mentioned sections, there seems good reason to suppose that the Radiolarian chert is present along the northern margin of Dartmoor in the same relative position above the *Posidonomya*-limestones and shales as in the other districts described in the present paper. More particularly there is a very close resemblance, both in the character of the chert and its relation to the associated limestones, to the beds exposed at the Wooladon quarry near Launceston (see p. 623).—July 22nd, 1895.]

EXPLANATION OF PLATES XXIII.–XXVIII.

PLATE XXIII.

Geological Sketch-map of Devon, West Somerset, and Cornwall, on the scale of 10 miles to the inch.

PLATE XXIV.

Section of the Radiolarian (Codden Hill) Beds of the Lower Culm Measures at Carzantic Quarry, near Launceston. From a photograph taken in March, 1895.

PLATE XXV.

The specimens figured in the following three Plates are all from the Radiolarian Beds of the Lower Culm Measures.

Figs. 1 *a*–1 *g*. *Sphærozoum*, sp. Detached spicules of various forms. From the Lower Culm Radiolarian rocks at Swimbridge, Heddon, and Kent's Hill, North Devon; Carzantic, near Launceston; Ramshorn Down; Winstow Lodge, near Chudleigh. ×200 diameters.

Fig. 2. *Cenosphæra pachyderma*, Rüst. Ramshorn Down, near Bovey Tracey, South-east Devon. ×200.

3. *Cenosphæra*, sp. *a*. From near Ashbrittle, Wellington, West Somerset. ×200.
4. *Carposphæra*, sp. *a*. Ramshorn Down, South quarry. ×200.
5. *Carposphæra*, sp. *b*. Artiscombe quarry, near Tavistock. ×200.
6. *Carposphæra*, sp. *c*. From a boulder of radiolarian chert at Tavistock. ×200.
7. *Carposphæra*, sp. *d*. Ramshorn Down, South quarry. ×200.
8. *Thecosphæra*, sp. *a*. From hedge-section, Lawell House, Chudleigh. ×200.
9. *Xiphosphæra*, sp. *a*. Ramshorn Down, North quarry. ×200.
10. *Xiphosphæra*, sp. *b*. Ramshorn Down, North quarry. ×200.
11. *Xiphostylus*, sp. *a*. Ramshorn Down. ×200.
12. *Xiphostylus*, sp. *b*. Showing traces of the lattice-structure, Ramshorn Down. ×200.
13. *Xiphostylus*?, sp. *c*. Ramshorn Down. ×200.
14. *Staurolonche*?, sp. *a*. Hedge-section, Lawell House, near Chudleigh. ×200.
15. *Stylosphæra*, sp. *a*. Ramshorn Down. ×200.
16. *Cenellipsis*, sp. *d*. Ramshorn Down. ×200.
17. *Druppula*, sp. *a*. Ramshorn Down. ×200.

[1] Trans. Devon. Assoc. vol. ii. (1867–68) p. 124.

PLATE XXVI.

Fig. 1. *Cenellipsis*, sp. *a*. Carzantic Quarry, near Launceston. ×200.
2. *Cenellipsis*, sp. *b*. Codden Hill Quarry, near Barnstaple. ×200.
3. *Theodiscus aculeatus*, sp. nov. Ramshorn Down, near Bovey Tracey. ×100.
4. *Lithocyclia devoniensis*, sp. nov. Ramshorn Down. ×200.
5. *Dorysphæra*, sp. *b*. Ashbrittle, near Wellington, West Somerset. ×100.
6. *Acanthosphæra laxa*, sp. nov. Ramshorn Down. ×100.
7. *Druppula*, sp. *b*. Carzantic Quarry, near Launceston. ×200.
8. *Cenellipsis*, sp. *b*. Codden Hill Quarry. ×200.
9. *Dorysphæra*, sp. *a*. Ramshorn Down. ×100.
10. *Ellipsoxiphus*, sp. *a*. Tregeare Down, near Launceston. ×100.
11. *Trigonocyclia*, sp. *a*. Ramshorn Down. ×100.
12. *Trigonocyclia*, sp. *b*. Ramshorn Down. ×100.
13. *Sethodiscus chudleighensis*, sp. nov. Hedge-section, Lawell House, Chudleigh. ×200.

PLATE XXVII.

Fig. 1. *Porodiscus percinctus*, sp. nov. Ramshorn Down. ×200.
Figs. 2, 3. *Porodiscus brevis*, sp. nov. Hedge-section, Lawell House, Chudleigh. ×200.
Fig. 4. *Porodiscus clathratus*, sp. nov. Ramshorn Down. ×200.
5. *Amphibrachium*, sp. *b*. Carzantic Quarry, near Launceston. ×100.
6. *Rhopalastrum ingens*, sp. nov. Ramshorn Down. ×75.
7. *Amphibrachium*, sp. *a*. Carzantic Quarry, near Launceston. ×100.
8. *Rhopalastrum*, sp. *a*. Ramshorn Down. ×75.
9. *Rhopalastrum clavatum*, sp. nov. Ramshorn Down. ×75.
10. *Porodiscus lens*, sp. nov. Hedge section, Lawell House, Chudleigh. ×200.
11. *Porodiscus percinctus*, sp. nov. Ramshorn Down. ×200.
12. *Porodiscus clathratus*, sp. nov. Ramshorn Down. ×200.
13. *Porodiscus*, sp. *a*. Ramshorn Down. ×200.
14. *Stichocapsa*, sp. *a*. Ramshorn Down. ×200.
15. *Lithocampe*, sp. *a*. Ramshorn Down. ×200.
16. *Lithostrobus*, sp. *a*. Heddon Quarry, near Barnstaple. ×200.
17. *Sethocapsa*, sp. *a*. Carzantic Quarry, near Launceston. ×100.

PLATE XXVIII.

The specimens figured in this Plate are all from the Radiolarian Beds of the Lower Culm Measures in North Devon.

Figs. 1, 1 *a*. *Phillipsia Leei*, H. Woodw. Glabella, enlarged 4 diameters, and detached cheek, enlarged 2 diameters. From Hannaford Quarry, near Barnstaple.
Fig. 2. *Phillipsia minor*, H. Woodw. Pygidium, enlarged 3 diameters. Hannaford Quarry.
3. *Phillipsia Cliffordi*, H. Woodw. A small imperfect specimen showing the head and tail. Enlarged 4 diameters. Combe Wood Quarry, Codden Hill, near Barnstaple.
3 *a*. *Phillipsia Cliffordi*, H. Woodw. A pygidium, enlarged 3 diameters. Hannaford Quarry, near Barnstaple.
4. *Phillipsia*, sp. Larval form. Enlarged 4 diameters. Hannaford Quarry.
Figs. 5, 5 *a*. *Griffithides acanthiceps*, H. Woodw. Detached free cheek, natural size. The eye of the same, enlarged 7 diameters. Hannaford Quarry. Collected by Mr. G. F. Tregelles.
Fig. 6. *Griffithides longispinus*, Portlock. Natural size. Codden Hill Quarry, near Barnstaple. Collected by Mr. J. G. Hamling, F.G.S.
Figs. 7, 7 *a*. *Proetus*, sp. *a*. Body-segments and pygidium, enlarged 4 diameters; and detached pygidium, enlarged 3 diameters. Codden Hill Quarry, near Barnstaple. Coll. Mr. J. G. Hamling.

Fig. 8. *Proetus*, sp. *b*. An imperfect specimen, enlarged 3 diameters. Combe Wood Quarry, near Barnstaple.

Figs. 9, 9 *a*. *Productus concentricus*, Sarres. Cast of the ventral valve. Natural size, and enlarged 2 diameters. Hannaford Quarry.

Fig. 9 *b*. *Productus concentricus*, Sarres. A specially wide form. Natural size. Hannaford Quarry.

Figs. 10, 10 *a*. *Productus plicatus*, Sarres. Cast showing traces of spines. Natural size, and enlarged 2 diameters. Hannaford Quarry.

Fig. 10 *b*. *Productus plicatus*, Sarres. Cast of the ventral valve, enlarged 2 diameters. Hannaford Quarry.

Figs. 11, 11 *a*. *Productus*, cf. *lævipunctatus*, Sarres. Internal cast of the ventral valve. Natural size, and enlarged 2 diameters. Hannaford Quarry.

Figs. 12, 12 *a*. *Chonetes rectispina*, von Koenen. Natural size, and enlarged 2 diameters. Hannaford Quarry.

Fig. 12 *b*. *Chonetes rectispina*, von Koenen. Cast of the dorsal valve, enlarged 2 diameters. Hannaford Quarry.

Figs. 13, 13 *a*. *Chonetes Laguessiana*, de Koninck. Cast of the ventral valve. Natural size, and enlarged 2 diameters. Hannaford Quarry.

14, 14 *a*. *Leptæna analoga*, Phill. Cast of valve. Natural size, and enlarged 2 diameters. Hannaford Quarry.

15, 15 *a*. *Orthotetes crenistria*, Phill., sp. Cast of the brachial valve. Natural size, and enlarged 2 diameters. Hannaford Quarry.

16, 16 *a*. *Spirifer*, sp. Internal casts of the dorsal or brachial valve. Natural size. Hannaford Quarry.

17, 17 *a*. *Athyris*, sp. Casts of the interior and exterior of the ventral valve. Natural size. Hannaford Quarry.

Fig. 18. *Pleurodictyum Dechenianum*, Kayser. Cast of a small specimen. Natural size. Hannaford Quarry.

18 *a*. The same. Cast of the basal portion of a larger specimen, showing the arrangement of the corallites. Natural size. Hannaford Quarry.

18 *b*. The same. Some of the corallites, enlarged 3 diameters, showing the disposition of the connecting pores.

Figs. 19, 19 *a*. *Cladochonus Michelini*, M.-Edw. & Haime. Cast of a single corallite and pedicel, showing vertical rows of pores in the calice. Natural size, and enlarged 3 diameters. Hannaford Quarry.

Fig. 20. *Petraia*, sp. Cast of the interior of the calice. Natural size. Hannaford Quarry.

20 *a*. The same. The base of the cast, showing the disposition of the septa and the rows of minute pores on either side of them. Enlarged 3 diameters.

Discussion.

The Chairman (Mr. W. H. Hudleston) remarked that such a paper as this proved that the subject of British geology was by no means exhausted. Notwithstanding the attention which had been paid to the several members of the Carboniferous system in Devonshire, the existence of a thick series, mainly of organic origin, on the horizon of the 'Codden Hill Grits' had hitherto been unsuspected. The correlation of these with the Millstone Grit had long ago been considered doubtful by him, but it had the sanction of authority. Besides the palæontological importance of a discovery like this, such a well-marked horizon might be useful in determining boundary-lines in areas where the Carboniferous and Devonian were much mixed up, as in the Tavistock district.

The Rev. G. F. Whidborne said that he had listened to the paper with interest, as he had visited the Codden Hill quarries last summer with Mr. J. G. Hamling, and had collected a number of fossils from

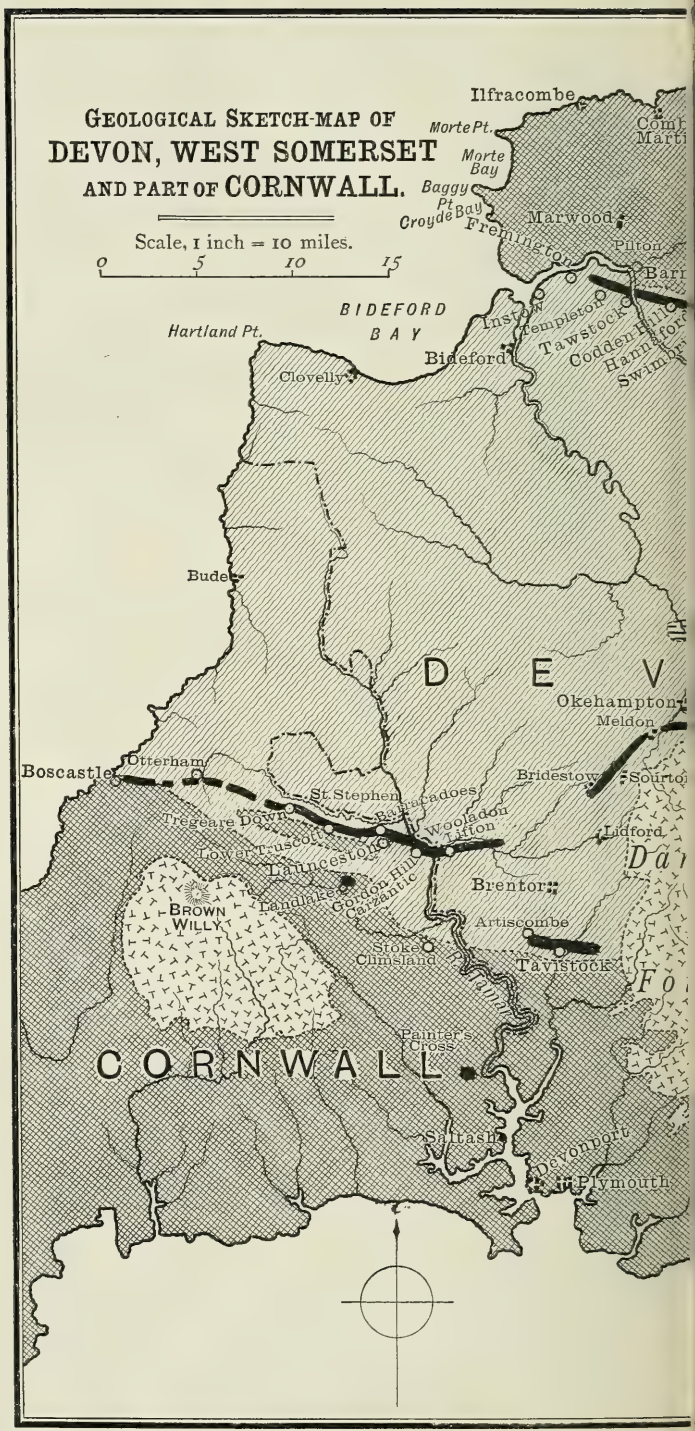
them. The new facts brought to light by the Authors had an important bearing upon the succession in some Devonian areas which he was now examining.

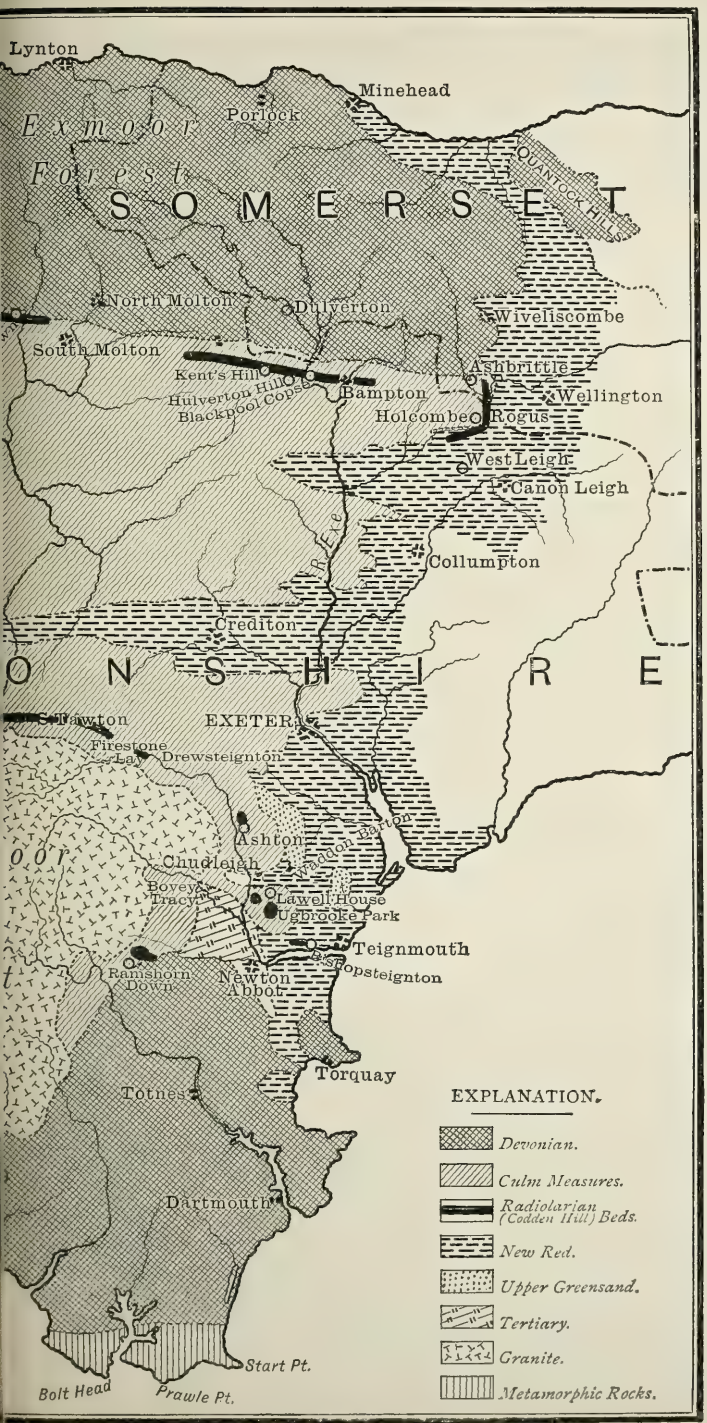
Mr. J. G. Hamling expressed his pleasure at being present on the occasion of the reading of this interesting paper—especially interesting to him, living as he did at the foot of Codden Hill. He entirely agreed with the conclusions arrived at by the Authors, and consequently had no criticism to offer. He might mention that he had himself traced the Radiolarian Beds from Dulverton to Fremington.

Dr. Hicks said that he had visited the quarries near Dulverton last year with Mr. Whidborne, chiefly to notice the gradual change in the deposits in ascending from the Pilton Beds. They subsequently visited South Pembrokeshire for the purpose of comparing the sections there with those in North Devon. There they found more calcareous matter, but also chert-bands, and the succession seemed to show a gradual passage from the Old Red to the Lower Culm Measures. They made a large collection of fossils from these rocks in Pembrokeshire, and they hoped ere long to bring the results before the Society. The paper by the Authors was, in Dr. Hicks's opinion, a most important one in its bearing on the succession in North Devon.

Mr. J. H. Collins congratulated the Authors on their very important discoveries, and had little doubt as to the justice of their conclusions, although he had no very intimate knowledge of the Culm Measures, his own work having been mostly among the much older rocks of the centre and west of Cornwall.

Sir Henry Howorth also spoke; and Dr. G. J. Hinde replied, thanking the Fellows for the reception accorded to his and Mr. Fox's paper.


GEOLOGICAL SKETCH-MAP OF
DEVON, WEST SOMERSET
AND PART OF CORNWALL.
Scale, 1 inch = 10 miles.
0 5 10 15
Ilfracombe
Morte Pt.
Morte Bay
Baggy Pt
Croyde Bay
Marwood
Puton
BIDEFORD
BAY
Hartland Pt.
Instow
Bideford
Clovelly
Bude
Okehampton
Meldon
Boscastle
Otterham
St Stephen
Bridestowe
Sourton
Tregeare Down
Roughtor
Brown Willy
Launceston
Lidford
Brentor
Gordon Hill
Carrantic
Artiscombe
Stoke Climsland
Tavistock
Painter's Cross
CORNWALL
Saltash
Devonport
Plymouth



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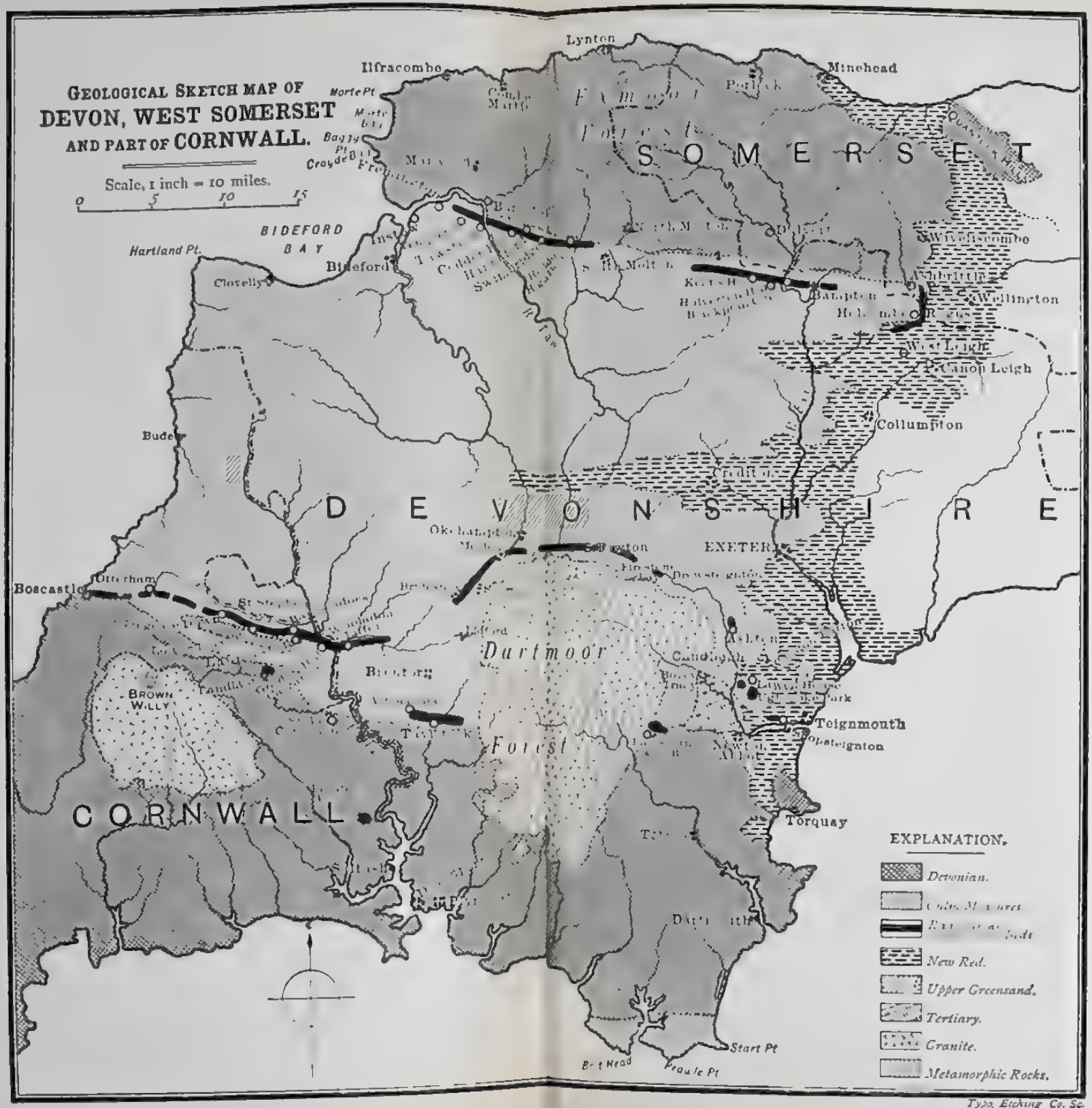

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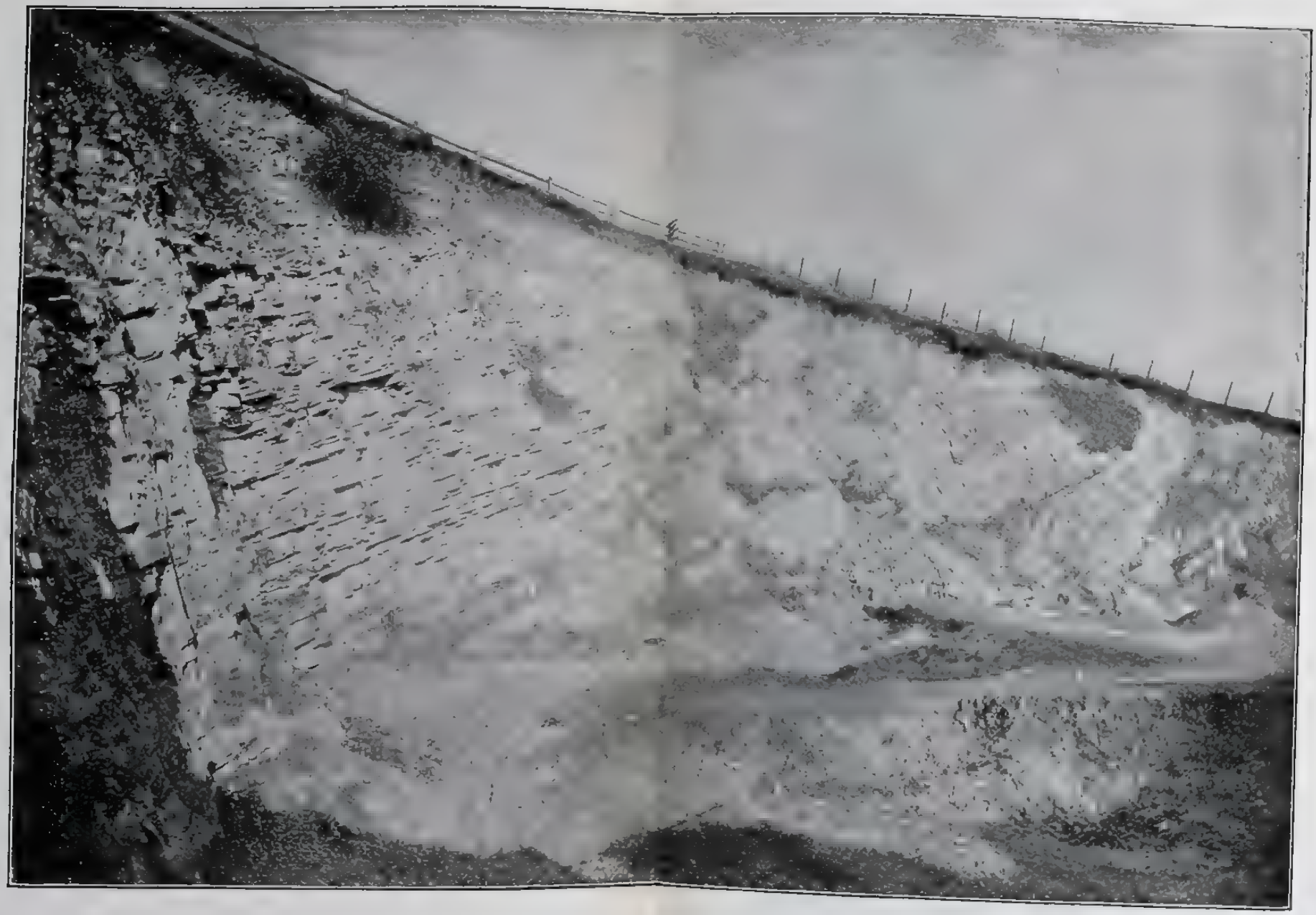
Section of the Radiolarian (Codden Hill) Beds of the Lower

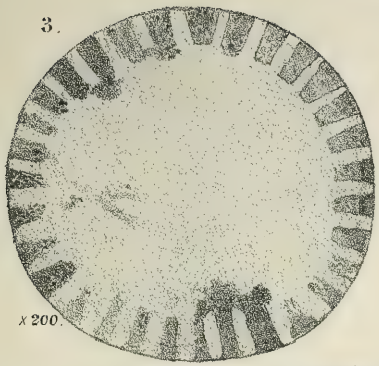
(From a photogra

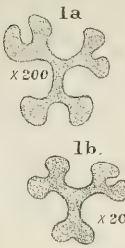
Measures, at Carzantic Quarry, near Launceston, Cornwall.
in March 1895.)

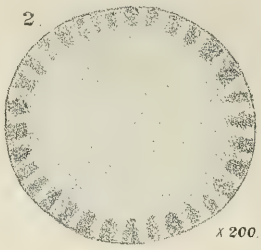


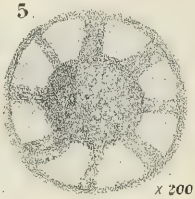
Section of the Radiolarian (Codden Hill) Beds of the Lower Culm Measures, at Carzantic Quarry, near Launceston, Cornwall.

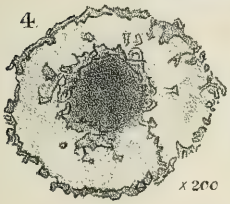
(From a photograph taken in March 1895.)

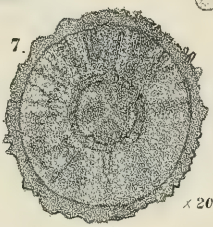


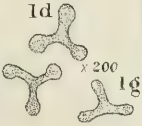


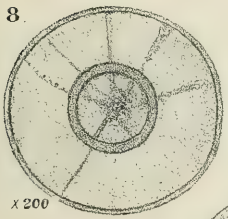


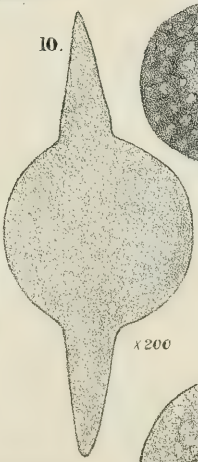


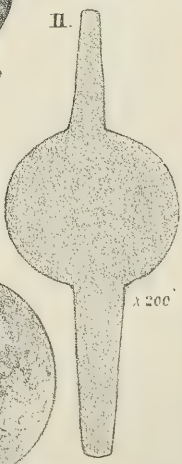


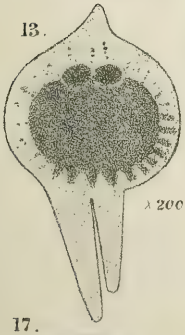


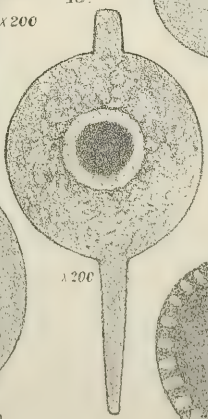


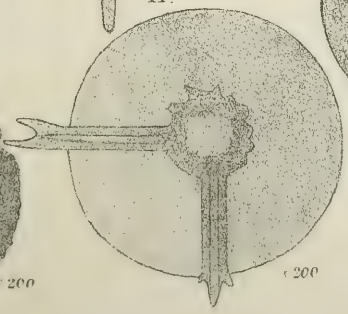


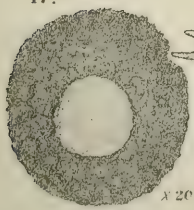












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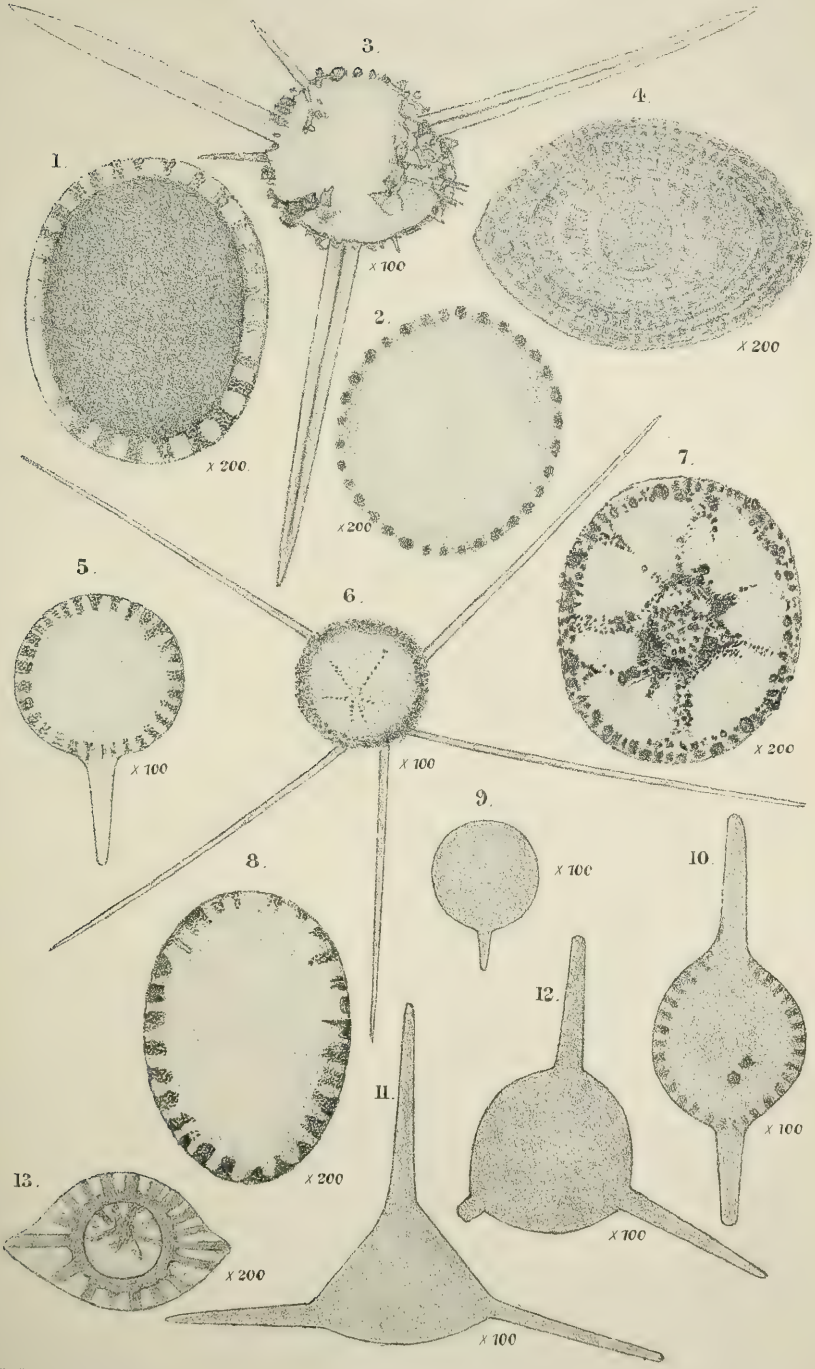
RADIOLARIA FROM THE LOWER CULM MEASURES.



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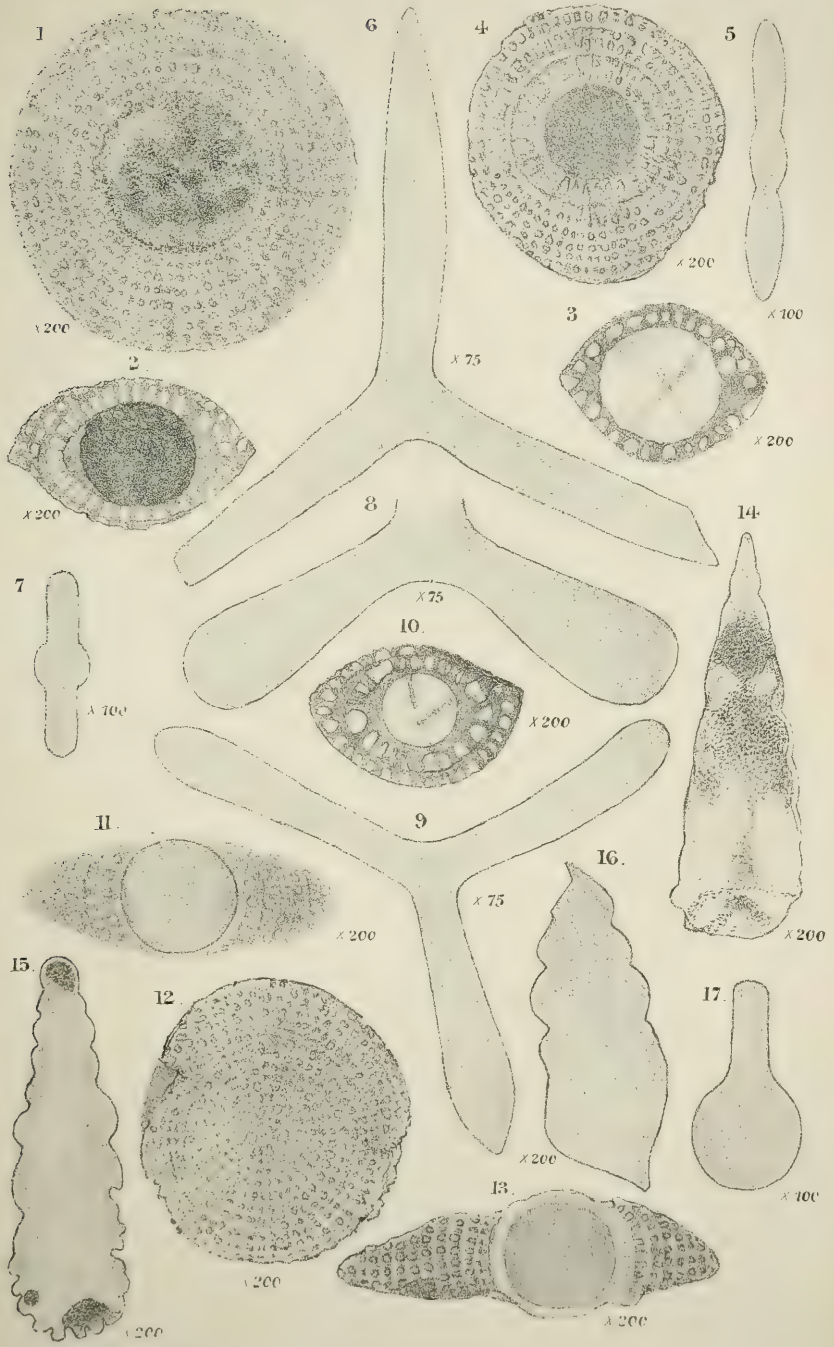

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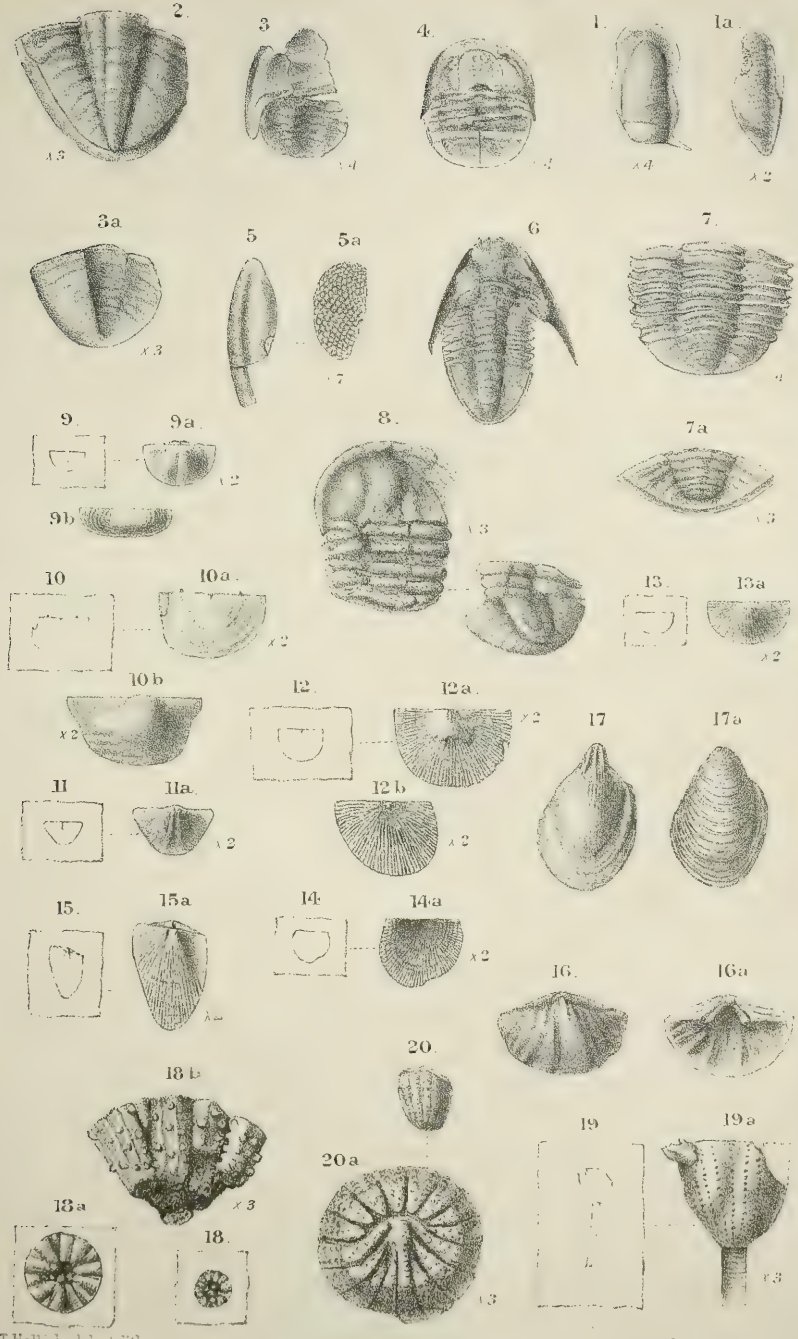

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TRILOBITES, BRACHIOPODS AND CORALS FROM THE RADIOLARIAN BEDS OF THE LOWER CULM MEASURES.

44. *The* Geology *of* Mount Ruwenzori *and* some Adjoining Regions *of* Equatorial Africa. By G. F. Scott Elliot, Esq., M.A., B.Sc., F.L.S., *and* J. W. Gregory, D.Sc., F.G.S. (Read June 5th, 1895.)

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I. Introduction.

Ruwenzori is a mountain-ridge on the right bank of the Semliki branch of the Nile, between the two lakes Mwutan and Lutan Nzige (the Albert and Albert Edward Nyanzas). It ranks as the third snow-capped mountain in Africa, both in height and date of discovery. Kilimanjaro was first seen in 1848 and Kenya in 1849, and Ruwenzori only narrowly escaped detection a few years later. Speke and Grant passed near it in 1862, but its existence was not reported to them, though the natives whom they met must have known of it. Sir Samuel Baker, in 1864, approached it from the north, and reached a locality from which the mountain ought to have been visible; but he did not see the snow, and though his 'Blue Mountain' seems to have been Ruwenzori, he covered the whole site of the mountain with a lake. Gessi Pasha circumnavigated the Albert Nyanza in 1876 and went nearer to the mountain than the point from which it was subsequently discovered; but he also missed it. Mason Bey, in 1877, followed the same course, and though he stayed for some time for astronomical purposes within sight of Ruwenzori, he never saw it. It was reserved for Mr. Stanley, in 1888, to recognize that the white patches that appeared among the clouds for brief and at distant intervals were a snow-capped ridge.

The late Capt. W. G. Stairs made an effort to ascend the mountain in 1889, and reached a level determined by aneroid barometer as 10,677 feet. All the high mountains of Equatorial Africa known at this time were volcanic, and this consideration no doubt helped Capt. Stairs to the belief that Ruwenzori also was an old volcano. In his report to Mr. Stanley he thus expresses his

conclusion:—'Many things go to show that the existence of these peaks is due to volcanic causes. The greatest proof that this is so lies in the numbers of conical peaks clustering round the central mass on the western side. These minor cones have been formed by the central volcano getting blocked in its crater.'[1]

For the first definite geological information about Ruwenzori we are indebted to Dr. Franz Stuhlmann, who visited the district with the late Emin Pasha in 1891. He ascended to the height of 15,000 feet (by aneroid), made some valuable botanical collections from it, and clearly showed that the volcanic theory could not be maintained. He says that 'the neighbourhood of the mountain, its aspect, and its massive cloud-formations have been described by Stanley with a master-hand. With his geological explanation I cannot, however, agree.'[2]

Stuhlmann's own interpretation of the mountain is that it is a 'faltungsgebirge' situated between two lines of dislocation. To the west is the great dislocation which runs along Tanganyika, up the valley of the Rusisi and Ruchuru, across the Albert Edward Nyanza and down the Semliki to the Albert Nyanza; to the east is a secondary dislocation which runs along Lake Ruisamba. Between these two lines is a mass of old eruptive rocks (granite and diabase), which has been forced up through the 'Urschiefer' (mica-schists, quartzite, and clay-slates), which have been thrown back. In his map he marks the whole mountain as diorite and diabase. It has therefore been generally regarded as a normal plutonic massif.

Topographically, Ruwenzori is a long narrow ridge which extends for about 50 miles in a direction from N.N.E. to S.S.W. Its summit attains the height of 16,500 feet, and thence there is a long eastward slope to the valley of the Wimi at Kyatwa. The slope to the west is at an angle of 22°, and that to the east at about one of 4°. The most convenient method of studying the geology of the mountain is therefore to make a few sections across it at right angles to its trend.

II. Sections across and Structure of Ruwenzori.

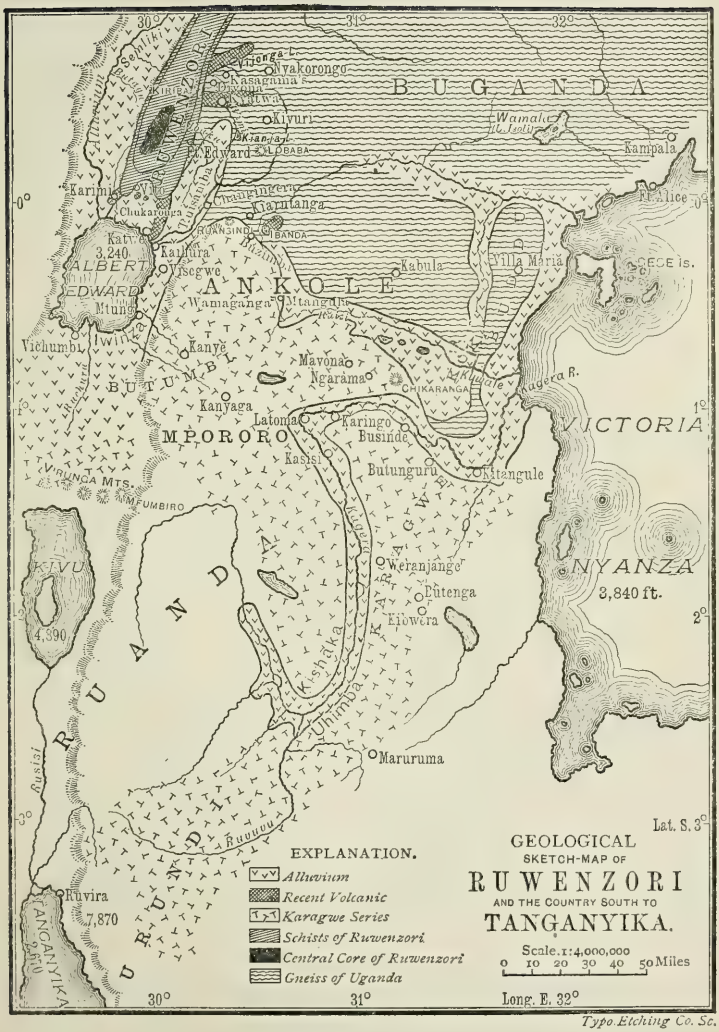
(1) The Kivata Section.

The first section will be taken from Kasagama's, westward along the course of the Kivata, past Diwona, to the summit of the northern end of the ridge of Ruwenzori. The country around Kasagama's is at the level of about 5200 feet, and is formed of hornblendic gneisses of a type common in the Archæan series of the Central African Plateau. In some cases [123][3] the rock has

[1] H. M. Stanley, 'In Darkest Africa,' 1890, vol. ii. p. 257.

[2] F. Stuhlmann, 'Mit Emin Pasha,' [1893] 1894, p. 298.

[3] The numbers in square brackets in the text are those of the specimens in the collection, which is now in the Mineralogical Department of the British Museum (Natural History).



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been intensely altered and consists of quartz, decomposed felspar, and chlorite. In places, as at the entrances to the Kivata and Butanuka valleys, the foliation becomes obscure. Following up the Kivata valley we come, at the level of 5600 feet, to a weathered foliated epidiorite [105]. At the levels of 6700 and 6800 feet there occurs a series of hornblendic schists interstratified with coarser gneissose rocks, which become in places syenitic gneisses. The hornblendic schists are succeeded in turn by a thick series of weathered, fairly coarse, and often much altered and decomposed gneissoid mica-schists [100 & 121] which extend up the mountain-face from 6900 to 9000 feet. There a banded epidiorite re-appears. A little farther up, at the highest point reached on this side, is a rock which, so far as the specimen available [107] allows us to judge, is a coarse pegmatite-dyke.

(2) The Yeria Section.

The second section up the eastern face of Ruwenzori was made a little farther south, along the valley of the Yeria, a tributary of the Wimi, a river which flows into the northern end of Lake Ruisamba. The section begins at the same level as the last (5200 feet), in the gneiss series of the district around Kasagama's. At the foot of the eastern slope, at the level of 6000 feet, the schist series is met with, and is here represented by a well-cleaved chloritic schist [103]. This is associated with rocks of which two different types are included in the collection. One [116] from the height of 6300 feet is a gneissoid schist containing quartzose felspathic nodules, though the specimen is too small to enable us to express a definite opinion as to its character. The other is a fine-grained, irregularly gneissoid syenite [104], which probably represents what was originally a series of intrusive dykes. Farther up the mountain-side, at the height of 8000 feet, another type of rock is met with: this [112] is a well-foliated hornblendic gneiss of medium grain. At 9000 feet occur soft, weathered mica-schists [117], while interbedded either in this or in the gneiss is a sheet of black, hard, massive epidiorite [108]. This rock does not, however, appear to constitute the mass of Ruwenzori; for still higher and nearer the central axis of the range we come to the weathered mica-schists, at 9800 feet, and a little higher yet there follows a hornblendic gneiss, which here appears to form the central axis of the chain.

(3) The Nyamwamba and Butagu Sections.

The last section described is of interest, as it reached the central axis of that part of the Ruwenzori ridge, which is there 11,000 feet in height. The third section is on the flanks of the highest part of the ridge, and both slopes are included, though unfortunately the summit was not itself reached. This attains here the height of

16,500 feet, but the highest specimens collected are from 9800 feet on the western and from 13,000 feet on the eastern side.

The eastern section follows up the valley of the Nyamwamba. It commences on a small lake (Kianja) a little north of Lake Ruisamba. At the height of 3240 feet it rises thence to the level of the gneiss plateau at 5200 feet. From this point to the 6000-foot contour there is a thick series of gneisses: one specimen of these [154] is a whitish gneiss of medium grain, containing muscovite, biotite, microcline, and numerous rounded blebs of quartz. The arrangement of the inclusions in the last-named of these minerals shows that they have been subjected to great strain. In this gneiss occur some beds of black, foliated epidiorite. At the level of 6000 feet the gneisses are succeeded by dark mica-schist. At 7000 feet the steep slope begins, but the whole surface is covered by bamboo-jungle, and no outcrop of rock could be found. At 10,000 feet the bamboos give place to peat-bogs, which are equally fatal to geological work. At 13,000 feet the base of a cliff is reached, the rock of which is a coarse granitoid gneiss. The specimen collected [140] consists in the main of a mass of schillerized orthoclase; quartz and microcline also occur in the rock, and it may be only a very coarse-grained variety of that previously described [154] below 6000 feet. This rock appears to continue to the height of 15,000 feet. The summit of the ridge is here 16,500 feet high.

Crossing to the western side and descending to the valley of Butagu, the section is resumed at the height of 9800 feet; for, though the height of 13,000 feet was reached, the whole slope was covered by peat and vegetation. From 7500 to 9800 feet the rocks are a series of schists; the specimen selected as a type [111] is a chlorite-schist, crowded with granules of magnetite, and containing crystals of muscovite and biotite and nodules of orthoclase. The whole rock has been intensely altered. There is a trace in it of what appears to have been a former foliation crossing that which now dominates in the rock. The highest mass of schist seen also shows signs of intense alteration, but the rock is of a somewhat different type. It is a contorted nodular mica-schist. At the base of the steep slopes of schist occurs a dyke of a basic rock about 100 yards in width; it occurs at the height of 7400 feet. The rock may be called an epidiorite, though in places there is no plagioclase left in it. Where least altered it consists of plagioclase and secondary hornblende; other specimens consist of crystals of hornblende, needles of actinolite in a quartz-matrix, with a little orthoclase. Rocks of the same type occur elsewhere on Ruwenzori in each of the other sections and at about the same horizon; thus in the Yeria valley they are seen between 8000 and 9000 feet, and in Kivata at 9000 feet. There is nothing exactly like them in the Archæan series farther east, but they remind us closely, both in macroscopic and microscopic characters, of some of the altered basic igneous rocks of Mashonaland.[1] The most typical rock is a true

[1] A. R. Sawyer, 'Goldfields of Mashonaland,' 1894, p. 14.

epidiorite, but in some cases alteration has proceeded farther and only a quartz-actinolite rock remains. In some places the rocks are coarser in grain and are roughly foliated, and they then offer some resemblance to the banded amphibolites which are such conspicuous members of the series of rocks of the Archæan plateau in British East Africa.

In the absence of more detailed information as to the field-relations of these rocks, we cannot prove conclusively their nature and origin. But the petrographic evidence suggests that the different varieties are all phases of one basic igneous rock altered by dynamo-metamorphic agencies.

From these rocks a long gradual slope, interrupted only by a cliff at 5000 feet, leads down to the alluvium beside the Semliki at a level of little over 3000 feet.

(4) Volcanic Rocks on the Plain around Ruwenzori.

It will be noticed in the sections previously described that no volcanic rock of recent date has been met with. Stuhlmann tells us that though it is naturally not impossible that one may find traces of volcanic activity such as lava, tuff, etc., nothing of the sort has yet been discovered.[1] Nevertheless, there is abundant evidence of recent volcanic action on the plains at the foot of Ruwenzori. Hot springs occur in several places, though we attach no value whatever to these. But the plains, especially to the east and south-east, are studded with small volcanic cones: the most northerly of these is at Vijonga, near Kasagama's. More than one of the cones contain a small, deep blue crater-lake, and the specimens from it [96] are a normal volcanic tuff. At Kyatwa is another circular lake, which is probably a crater-lake, and the hill beside it is possibly the remains of an old volcanic cone. The specimen of sand collected from this [153] is composed of volcanic materials, but has possibly been re-arranged by water; another specimen, however, is obviously a recent volcanic agglomerate. At Chukaronga is another crater-lake; between this and the shore of Ruisamba are two more, and at Katwe is yet another. Moreover, between Katwe and Chukaronga runs a ridge of old Archæan rocks, including a foliated epidiorite [166], which is capped in places by an olivine-basalt [152], the appearance of which is very fresh.

There is, therefore, no doubt that volcanic action has taken place on the plain at the foot of Ruwenzori, and both the persistence of the craters and the freshness of the rocks indicate that they are of comparatively recent age. These craters are arranged on lines which radiate outwards from Ruwenzori.

[1] Stuhlmann, 'Mit Emin Pasha,' [1893] 1894, p. 298.

(5) Conclusions as to the Structure of Ruwenzori.

After this description of the facts observed it is advisable to consider the evidence which they afford as to the character of the mountain. There are three rival explanations. The first view is that it is volcanic; the second, that of Stuhlmann, is that it is a plutonic massif of diorite; to which we add a third, that it is possibly a 'block-mountain.'

We do not presume to be able to give a final solution to this problem, for it is possible that in the heart of the ridge there may be rocks different from any yet found. The volcanic theory, however, may be at once dismissed, and the evidence is equally conclusive that Ruwenzori is not a simple massif of diorite. This rock apparently occurs only as banded sheets in the schists, and is not the central rock of the ridge. The plutonic is, nevertheless, a possible theory.

The strike of the schists on the flanks of the mountain seems to run concentrically round the ridge. This certainly looks as if the central rock were intrusive into the schists.

The highest rock as yet collected is not sufficiently definite to prove either one theory or the other. It is a coarse-grained felspathic rock [140], which consists mainly of a large crystal of schillerized orthoclase, and contains some quartz and microcline. The rock is either a granite or a granitoid gneiss, probably the latter. It was doubtless originally an igneous rock, and may owe the foliation which probably occurs in it, either to fluxion during cooling (as in the case of intrusive gneisses) or to dynamo-metamorphism. It may be, therefore, either an intrusive igneous rock, or a part of the old Archæan series faulted up. There is nothing in the microscopic characters of this rock to separate it from those of the Archæan series.

Unless further investigation bring to light other rocks in the centre of the ridge, we think it probable that this rock will be proved to have been raised into its present position by faulting. In this case Ruwenzori is simply composed of an orographic block or 'scholl.'

III. The Glaciation of Ruwenzori.[1]

The Yeria, Msonje, and Wimi valleys have the ordinary **V** shape of erosion-valleys in a tropical and rainy climate, but the Mubuku and Nyamwamba valleys are quite different. They are flat and broad, with the open **U** shape which is most usual in glacier-formed valleys. Another valley (the Butagu) on the western side is neither one nor the other, but has the general shape of the latter, with a deep ditch at the bottom.

It seemed to me afterwards that this rather pointed to the Nyamwamba, Mubuku, and Butagu valleys having been at one

[1] This part is contributed solely by Mr. Scott Elliot.

time occupied by glaciers. The following evidence may perhaps be considered as supporting this view:—

1. Roches moutonnées of the typical rounded kind are common in the Mubuku valley; but, especially in the Nyamwamba valley, one sees occasionally enormous rounded boulders 10 feet high.

2. These three valleys are the only ones that I saw which led directly to the snow-peaks.

3. The accumulations of stones and gravel in both the Nyamwamba and Mubuku valleys. These are made up of large stones frequently 4 feet in diameter, and sometimes they form, as for example at the mouth of the Mubuku and Sebwe rivers, banks 30 feet above the present height of the river.

I did not at the time realize the importance of this question, and possibly the evidence is not satisfactory; a height of about 5000 feet would be nearly that of the flat valley-bottoms of the Mubuku and Nyamwamba valleys, and this would also be that of the rounded part of the Butagu valley, though in this latter case the present level of the stream is very much lower, as it has cut a deep and narrow channel for itself.

The quantity of snow on Ruwenzori is at present so small that it seems unlikely that so great an amount of erosion could have been produced; but, taking into account the length of the snow-ridge and the higher altitude of the mountain in former times, it seems to me highly probable that glaciers did once extend down to this level.

This conclusion was announced in a letter to 'Nature,' Jan. 17th, 1895 (vol. li. p. 271), in which the belief was expressed that 'glaciers must have extended 7 to 8 miles down two of the valleys.' It should also be remembered that Stuhlmann[1] quotes Emin and Casati as having come to the conclusion that glaciation occurred in this district, the latter even claiming to have found striæ. Stuhlmann, however, was himself unable to confirm these conclusions.

IV. The Geology of the Country around Ruwenzori.

(1) The Archæan Series.

Leaving Ruwenzori for the surrounding country, we find that this consists of rocks which may be conveniently grouped into two series, one composed of gneisses and schists, and the other of non-foliated sediments. The former are of the type that has an enormous extension in Equatorial Africa, and forms the main plateau on which all the sediments and volcanic rocks have been deposited. On the march from the coast, the rocks of this series are struck a short distance inland from Mombasa, and are crossed through Taita, Tzavo, Kikumbuliu, and the Iveti Mountains to Machako's. There they plunge below volcanic rocks which extend westward to the summit of Mau. The gneisses were known to reappear in Buganda

[1] 'Mit Emin Pasha,' [1893] 1894, p. 298.

and Busoga, but the western limit of the volcanic rocks was uncertain.

The Archæan rocks are first seen at the western foot of the Nandi Hills, and extend thence across a wide extent of country in Northern Kavirondo. Around Mumia's the series is represented by a fine-grained syenitic gneiss, almost identical in character with some in the Taita Mountains. The gneissic series extends thence along the northern shore of the Victoria Nyanza, through Busoga, Buganda, and Buddu; it disappears at length beneath the sediments of Karagwe and Ankole at Butunguru, a little to the west of Kitangule, on the last great bend of the Kagera River. Then the Archæan rocks appear again farther west, at Kiarutanga and Kasagama's, and form the whole platform on which Ruwenzori rests.

(2) The Sedimentary Rocks.

Speke[1] has recorded the existence of a series of sedimentary rocks on the western slopes of the Nyanza basin, in the districts of Karagwe and Ankole. More recently, the late Mr. Joseph Thomson[2] recorded the occurrence of a wide expanse of old sediments in the upper part of the Congo Basin, where they have been described in some detail by M. Cornet.[3] In the absence of fossils it is impossible to correlate the various members of this series or determine their ages. Shales of Permo-Carboniferous age occur on the Sabaki, and there are general reasons for considering that the sedimentary formations of the interior are older than these. It is therefore probable that they are Palæozoic, and possibly pre-Carboniferous; but beyond this very indefinite conclusion it is unsafe to go.

The Nandi Hills afford the first opportunity for a study of these sedimentary rocks, and here their superposition on the gneiss can be clearly seen.

The lower part of the eastern slope is formed of a fine quartzite containing a little mica [35]. Followed up the hill, this is succeeded by a black, massive, cherty-looking quartzite [36], which is apparently continuous with a coarser pink quartzite [39]. The main part of the western slope is occupied by a series of amphibolite-schists [40] which rest on a fine-grained syenitic gneiss [41], both of which must belong to the Archæan series. The summit of the hills is occupied by a mylonitic gneiss [38] which is apparently interbedded in the quartzites, and thus belongs to the sedimentary and not the Archæan series. The foliation of this gneiss is vertical, and its characters are very different from any in the Lower Archæan series.

After leaving the Nandi Hills the gneisses are crossed as far as

[1] J. H. Speke, 'Journal of the Discovery of the Source of the Nile,' 1863. p. 196.

[2] Jos. Thomson, 'To Lake Bangweolo and the Unexplored Region of British Central Africa,' Geogr. Journ. vol. i. (1893) pp. 116–117.

[3] J. Cornet, 'Les Formations Post-Primaires du Bassin du Congo,' Ann. Soc. géol. Belg. vol. xxi. (1895) Mém. pp. 193–279.

the Samia Hills, which are of interest, as they appear to be formed of a synclinal set of sedimentary rocks, at the base of which occur the ironstones around Berkeley Bay. The ore occurs in pockets 40 yards in diameter, which are scattered in a bed about 200 feet thick; the strike is from N.N.E. to S.S.W., and the bed dips 80° east.

The ore is a red hæmatite, and for several assays of this we are indebted to Mr. W. Tate, F.C.S., of the Royal College of Science, South Kensington. He reports as follows:—

Analyses of Iron Ore.

No. 55.—Dark red, in bulk and in powder. The ore was comparatively soft. It contained, among other things, phosphorus in appreciable amount, and silica in very considerable quantity, but no sulphur or titanium. Percentage of iron = 41·08.

No. 56.—Dark red in bulk; when ground to powder, dirty yellow. The ore was very hard. It contained, among other things, sulphur and phosphorus in appreciable amount; of titanium only a trace. Percentage of iron = 61·69.

No. 59.—Very refractory, only partially dissolved by nitric acid and potassium chlorate. Substances present: alumina, silica, phosphate, traces of sulphate, carbonate, and titanium.

A sample of the ore (not including the white portion) was made and finely ground. Weighed portions were fused with potassium bisulphate, dissolved in acid, and the iron estimated by permanganate solution. Mean result = 43·21 % iron.

The Karagwe Series.—The occurrence of sedimentary rocks in Karagwe was first reported by Speke from the evidence collected by himself and Grant. The rocks here are more extensive than those of the eastern side of the Nyanza, and may be part of the series that occupies an enormous tract of country in the upper basin of the Congo.

The rocks of this series occur throughout almost the whole of Karagwe, Ankole, and Koki. They may be divided into four main groups, which occur in the following sequence:—

1. Granular quartzite.
2. A coarse schistose sandstone.
3. A series of red and brown sandstones containing beds of hæmatite.
4. A series of argillaceous beds which range from shales to a well-cleaved killas.

The rocks are inclined at a high dip, and have been so much contorted that it is difficult to form an idea of their thickness. But as they extend from Butunguru on the Kagera river to Kiarutanga, a distance of about 100 miles, and numerous valleys from 1000 to 1200 feet in depth have been cut through them without reaching the gneiss, there can be no doubt that they are of great thickness.

In the Ruampala Mountains the rocks of this series are associated with a number of iron ores which occur in approximately the same position as those of the Samia Hills. The ridges are crowned with a granular quartzite, while the rock near the gneiss is a coarse schistose sandstone. The actual junction-rock near Kiarutanga [89*] is a laminated, micaceous sandstone, which appears to have been to some extent flattened out by pressure. Elsewhere, as at Tiasimbe, the rock in contact with the gneiss series is a red sandstone, so that the sedimentary series no doubt rests unconformably on the Archæan rocks.

The extent to which the rocks have been altered varies considerably. In some cases the rocks are simple massive sandstones (as at Tiasimbe) or altered shales (as at Ruetembe on the Kagera); in others they have been crushed into schistose quartzites and hard, siliceous slates with imperfect foliation (as in the Ruampala Mountains), or into a well-cleaved clay-slate or killas (as at Kitangule).

The rocks around Ujiji are probably part of the same series. They are coarse quartzose grits, red, iron-stained, and yellowish sandstones. At Niamkorio, at the southern end of Tanganyika, a white laminated sandstone appears to represent the same series.

Discussion.

The Chairman (Mr. W. H. Hudleston) congratulated the Society on having received a geological paper from two distinguished geographers, since he had always regarded geography and geology as sister sciences. We are told of the effects both of fire and frost in this remarkable region. As regards the former, he owned to a feeling of disappointment that Mount Ruwenzori proves not to be a volcano. It would seem to belong to a not uncommon type of mountain, where a granite core is flanked by various schists, though the Authors had suggested and possibly favoured another alternative.

Dr. Blanford called attention to the fact that Ruwenzori was the only instance known of a mountain in Africa south of the Tropic of Cancer that exceeded 10,000 feet in height and was not composed of volcanic rocks. He enquired about the lowest elevation at which glacial markings occurred, and noticed that the discovery of these markings on a second Central African peak was rather opposed to Dr. Gregory's view that Kenya had been depressed. On the other hand, no glacial markings appeared to have been observed on Kilimanjaro, and the speaker had looked for them unsuccessfully in Abyssinia at 10,000 feet above the sea. The evidence of biological distribution was in favour of a general refrigeration of the earth's surface in Pleistocene times.

Sir Henry Howorth also spoke.

Mr. Scott Elliot said that, with regard to the authorship of this paper, his work had merely consisted in bringing back speci-

mens and making very insufficient field-notes. The level to which glaciation had occurred—that is, if it really did occur, for he was by no means certain on the point—was about 5200 feet in all the three valleys. The present snow-line is 15,000 feet at lowest, and this seems at first sight to be an enormous difference. The mountain may, however, have been once very much higher. The interesting point in African geology would be to know in what condition the Sahara was in Miocene times: his experience in botany was that one might roughly divide the whole flora of Africa into two parts by a line passing along Ruwenzori from the Abyssinian mountains, by the east of Tanganyika and the Stevenson Road to Angola. In view of this fact, Dr. Blanford's remarks were of the very greatest interest. He was very grateful to Dr. Gregory for the great care and thoroughness with which he had worked out his collection.

He also mentioned that Capt. Lugard appears to have discovered the recent volcanic cones near Ruwenzori as well as crater-lakes on the eastern side of the Albert Edward Nyanza, though this is not very clearly put in his work.

Dr. Gregory remarked that the collection from Ruwenzori did not contain a definite plutonic rock, though one might ultimately be found. There was no evidence of the former extension of the glaciers of Kilimanjaro, and he had searched in vain for evidence of such on mountains a little over 10,000 feet in height. It was only where this level was much exceeded, so that great snow-fields existed, that the glaciers ran to lower levels.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1894–95.

November 7th, 1894.

Dr. Henry Woodward, F.R.S., President, in the Chair.

George Edward Dibley, Esq., St. Michael's School, Lower Sydenham, S.E., was elected a Fellow of the Society.

The List of Donations to the Library was read.

Sir John Lubbock exhibited specimens of fossiliferous limestones from the valley of Lauterbrunnen at Mürren, some little way below the Hotel. He pointed out the locality to Mr. Etheridge, who would also exhibit some specimens. The specimens contain *Nummulites Ramondi*, *Orbitoides dispansus*, etc., as determined by Prof. T. Rupert Jones.

Mr. Etheridge referred to the position of the Orbitoidal limestones on the slope of the Mürrenberg, and stated that Prof. T. R. Jones had examined and named the foraminifera, etc. contained in the several specimens collected by Sir John Lubbock and himself at Mürren.

Prof. T. Rupert Jones stated that this rock contains small Nummulites like *N. Ramondi* thinly scattered throughout the mass. Also numerous larger discoidal forms, having brown interiors and whitish exteriors, which seem to be *Orbitoides*, matching *O. dispansus* in size, and of which the inner parts have been altered by iron oxide. Von Gümbel has figured something like it. Both the *Nummulites* and *Orbitoides* mostly lie parallel with the laminæ of the shearing, but in some cases at different angles. There are also some small pieces of Nummulitic shell. At least one Rotalian shell is visible in section. Fragments of polyzoa are recognizable. The

outline of a thin-shelled echinoid is traceable on the broken surface of one small block. The abundant greyish-white laminæ under the microscope look like a minutely quasi-areolar tissue. This may be mylonized organic structure—of echinoderms, or polyzoans, or calciferous algæ. There are darker lenticules of possibly some fragments of a limestone different from the enclosing mass. Also small specks of calcite and some grains of quartz.

The following communications were read:—

1. 'Notes on some recent Sections in the Malvern Hills.' By Prof. A. H. Green, M.A., F.R.S., V.P.G.S.

2. 'The Denbighshire Series of South Denbighshire.' By Philip Lake, Esq., M.A., F.G.S.

3. 'On some Points in the Geology of the Harlech Area.' By the Rev. J. F. Blake, M.A., F.G.S.[1]

The following specimens were exhibited:—

Specimens and microscope-sections of Nummulitic Limestone (sheared) containing *Nummulites Ramondi*, Defrance, *Orbitoides dispansus* (Sowerby), *Orbitoides papyraceus* (Boubée)—large form; also remains of Echinoderms (?), Polyzoans, Rotalians, etc., from Mürren, Bernese Oberland, exhibited by Sir John Lubbock, Bart., M.P., F.R.S., F.G.S.

A series of specimens of the same rock, exhibited by R. Etheridge, Esq., F.R.S., F.G.S.; also three by Prof. T. McKenny Hughes, M.A., F.R.S.

Chelæ of a large Lobster from the Portland Stone, Isle of Portland, exhibited by the President.

Rock-specimens and microscope-sections of Malvern Rocks, exhibited by Prof. A. H. Green, M.A., F.R.S., V.P.G.S., in illustration of his paper.

Rock-specimens of the Denbighshire Series of South Denbighshire, exhibited by Philip Lake, Esq., M.A., F.G.S., in illustration of his paper.

A Stalactite and a toe-bone of a Mammal, found in a stony torrent-bed, flowing between sandstone hills. The stream is about 15 miles east of Anping, Formosa, and the altitude of the hills between 50 and 100 feet. Exhibited by J. W. Carrall, Esq., F.G.S.

Photograph of a Vertical Section of a typical sample of Coal of the 'Pittsburg' seam, in S.W. Pennsylvania, exhibited by W. S. Gresley, Esq., F.G.S.

Photograph of an erect stem of *Sigillaria* (Coal Measures), Valley of the Roach, Rochdale, exhibited by Sir Henry Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

[1] Withdrawn by permission of the Council.

November 21st, 1894.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Boverton Redwood, Esq., F.R.S.E., F.C.S., Assoc.Inst.C.E., 4 Bishopsgate Street Within, E.C., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Pleistocene Beds of the Maltese Islands.' By John H. Cooke, Esq., B.Sc., F.G.S.

2. 'Geological Notes of a Journey in Madagascar.' By the Rev. R. Baron, F.L.S., F.G.S.

3. 'On a Collection of Fossils from Madagascar obtained by the Rev. R. Baron.' By R. Bullen Newton, Esq., F.G.S.

The following specimens were exhibited:—

Opalized Cretaceous Fossils, consisting of a tooth of *Polyptychodon*, the guard of a *Belemnitella*, and a bivalve shell, from New South Wales, exhibited on behalf of Messrs. Gilbert John McCaul & Co., by the President.

Precious Opal having the form of *Natica*, exhibited on behalf of Mr. S. Henson by the President.

Beekites from Mexico, exhibited on behalf of the Rev. John Gerard, S.J., by the President.

Specimens and photographs of places in the Maltese Islands, exhibited by J. H. Cooke, Esq., F.G.S., in illustration of his paper.

Specimens and microscope-sections, exhibited by the Rev. R. Baron, F.G.S., and R. Bullen Newton, Esq., F.G.S., in illustration of their papers.

December 5th, 1894.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Prof. Frank Dawson Adams, M.A.Sc., Ph.D., 393 Guy Street, Montreal, Canada; Edward Michael Eaton, Esq., Mosborough Hall, Rotherham; the Rev. Mark Fletcher, B.A., Broom House, Broom, Durham; Charles Irving Gardiner, Esq., Epsom College, Epsom; George Ernest Grimes, Esq., Assoc.R.S.M., Redhill, Surrey; Joseph G. Hamling, Esq., The Close, Barnstaple, N. Devon; Alfred James, Esq., 108 A Hope Street, Glasgow; E. M. Jones, Esq., B.A., Leamington College, Leamington; James Andrew Mactear, Esq., 171 Victoria Street, S.W.; Patrick Marshall, Esq., M.A., B.Sc., Lincoln, Canterbury, New Zealand; Arthur Llewellyn

Pearse, Esq., 13 St. Helen's Place, E.C.; John Ashmead Pruen, Esq., M.A., Romsdal, Guildford; Prof. James Edward Talmage, Ph.D., University of Utah, Salt Lake City, Utah, U.S.A.; and William White, Esq., Charters Towers, Queensland, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Supplementary Note on the Narborough district (Leicestershire).' By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in University College, London.

2. 'The Tarns of Lakeland.' By J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.

3. 'Description of an Instrument for Surveying by the Aid of Photography, with some Observations upon the Applicability of the Instrument to Geological Purposes.' By J. Bridges Lee, Esq., M.A., F.G.S.

4. 'The Marble Beds of Natal.' By David Draper, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of rocks and microscope-sections, exhibited by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., in illustration of his paper.

An Instrument for Surveying by the Aid of Photography, exhibited by J. Bridges Lee, Esq., M.A., F.G.S., in illustration of his paper.

A specimen of *Clypeus* from Malta (?), and specimens of Silicified Wood (Monocotyledonous) from Sardinia, exhibited by W. F. Gwinnell, Esq., F.G.S.

Photographs illustrating geological features in the departments of the Doubs, Haute Loire, Basses Alpes, Alpes Maritimes, and Var, exhibited and presented by James Jackson, Esq., Honorary Librarian of the Geographical Society of France.

December 19th, 1894.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Arthur J. Heath, Esq., The College, Monkton Combe, Bath; Frederick Augustus Thompson, Esq., 93 Oxford Gardens, North Kensington, W.; and Carlos von Zeller, Esq., Camborne, Cornwall, were elected Fellows; Prof. G. J. Brush, Yale University, New Haven, Conn., U.S.A., was elected a Foreign Member; Dr. F. P. Moreno, La Plata Museum, La Plata, and Dr. A. Rothpletz, Munich, were elected Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Lower Greensand above the Atherfield Clay of East Surrey.' By Thomas Leighton, Esq., F.G.S.

2. 'On the Eastern Limits of the Yorkshire and Derbyshire or Midland Coalfield.' By W. S. Gresley, Esq., F.G.S.

3. 'On some Phases of the Structure and Peculiarities of the Iron Ores of the Lake Superior Region.' By W. S. Gresley, Esq., F.G.S.

The following specimens were exhibited:—

A series of specimens of the Lower Greensand above the Atherfield Clay of East Surrey, and specimens of Chert and Bargate débris from Drift and Alluvium, south and south-east of Dorking, exhibited by Thomas Leighton, Esq., F.G.S., in illustration of his paper.

Two specimens of Iron Ore from the Lake Superior Region, exhibited by W. S. Gresley, Esq., F.G.S., in illustration of his paper.

January 9th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Henry M. Cadell, Esq., B.Sc., F.R.S.E., Grange-by-Borrowstounness, West Lothian, was elected a Fellow of the Society.

The following Fellows, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—

Lieut.-General C. A. McMahon and F. W. Rudler, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Formation of Oolite.' By E. B. Wethered, Esq., F.G.S.

2. 'On the Lias Ironstone around Banbury.'[1] By Edwin A. Walford, Esq., F.G.S.

3. 'Notes on the Geology and Mineral Resources of Anatolia (Asia Minor).' By W. F. Wilkinson, Esq., F.G.S.

[1] Withdrawn by permission of the Council.

The following specimens were exhibited:—

Microscopic sections of oolites, and photographic enlargements, shown on the screen by means of a lantern, exhibited by E. B. Wethered, Esq., F.G.S., in illustration of his paper.

Specimens of the Lias Ironstone around Banbury, exhibited by Edwin A. Walford, Esq., F.G.S., in illustration of his paper.

Oolitic sand from the shore of Great Salt Lake, Utah, U.S.A., and various microscope-sections of oolitic structure, exhibited by Dr. G. J. Hinde, V.P.G.S.

Coral from the Lower Lias of Lussay, near Broadford, Skye, and oolitic limestone from the Lower Lias of Applecross, Ross-shire, collected by Horace B. Woodward, Esq., F.G.S. Exhibited by the Director-General of the Geological Survey.

Rock-specimens from Anatolia (Asia Minor), exhibited by W. F. Wilkinson, Esq., F.G.S., in illustration of his paper.

Specimen of *Ammonites catinus* (Mantell), Middle Chalk (Melbourne Rock), from Buckland Chalk Pit, Buckland, Surrey, exhibited by G. E. Grimes, Esq., F.G.S.

Tooth of *Cestracion rugosus* from the Lower Chalk, Warlingham, Surrey, exhibited by G. E. Dibley, Esq., F.G.S.

January 23rd, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Carrock Fell: a Study in the Variation of Igneous Rock-masses. Part II. The Carrock Fell Granophyre. Part III. The Grainsgill Greisen.' By Alfred Harker, Esq., M.A., F.G.S.

2. 'The Geology of the Country around Fishguard (Pembrokeshire).' By F. R. Cowper Reed, Esq., M.A., F.G.S.

3. 'On the Mean Radial Variation of the Globe.' By J. Logan Lobley, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of the Carrock Fell granophyre and its basic modifications, and specimens of Grainsgill greisen illustrating its relation to the Skiddaw granite, exhibited by Alfred Harker, Esq., M.A., F.G.S., in illustration of his paper.

Specimens from the Fishguard area and microscope-sections, exhibited by F. R. Cowper Reed, Esq., M.A., F.G.S., in illustration of his paper.

Model to show the amount of folding given by a surface-contraction of 2·5 per cent. or $\frac{1}{40}$, exhibited by J. Logan Lobley, Esq., F.G.S., in illustration of his paper.

February 6th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Robert Henry Byles, Esq., Elton, Stockton-on-Tees; Major Charles Myles Officer, Melbourne Club, Melbourne, Victoria; Samuel Warren Price, Esq., Assoc.R.S.M., 10 Broomhouse Road, Fulham, S.W.; and George H. Winstanley, Esq., Oak House, Eccles Old Road, Pendleton, Manchester, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On Bones of a Sauropodous Dinosaur from Madagascar.' By R. Lydekker, Esq., B.A., F.R.S., V.P.G.S.

2. 'On the Physical Conditions of the Mediterranean Basin which have resulted in a Community of some Species of Freshwater Fishes in the Nile and the Jordan Waters.' By Prof. E. Hull, M.A., LL.D., F.R.S., F.G.S.

3. 'On the Loess and other Superficial Deposits of Shantung (Northern China).' By S. B. J. Skertchly, Esq., and T. W. Kingsmill, Esq., C.E. (Communicated by Sir John Evans, K.C.B., F.R.S., F.G.S.)

The following specimens were exhibited:—

Specimens of Bones of a Sauropodous Dinosaur from Madagascar, exhibited by R. Lydekker, Esq., B.A., F.R.S., V.P.G.S., in illustration of his paper.

A specimen with *Anodonta* from the Lower Old Red Sandstone of Talgarth (Llanvaches) by Caerleon (Mon.), exhibited by Prof. H. G. Seeley, F.R.S., F.G.S., on behalf of Percy Hawkins Esq.

ANNUAL GENERAL MEETING,

February 15th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Report of the Council for 1894.

In once again congratulating the Fellows on the satisfactory condition of the Society's finances, the Council have pleasure in pointing out that the decrease in the number of Fellows, to which attention was drawn in the two previous annual reports, has been much less apparent during the year under review. For 1893 the Council announced an actual decrease of 46 Fellows, while in 1894 the decrease is 11.

The number of Fellows elected into the Society during 1894 was 48, of whom 36 paid their fees before the end of the year, while fees were received from 7 previously elected Fellows, thus making the total accession of new Fellows amount to 43 during the twelvemonth.

During the same period, however, there was a total loss of 54 Fellows—20 by death, 19 by resignation, 13 removed from the list because of non-payment of their Annual Contributions, and 2 non-Contributors removed from the list after having remained thereon for many years without any known address.

The actual decrease in the number of Fellows is, therefore, as above stated, 11.

Of the 20 Fellows deceased, 4 were Compounders, 13 were Contributing Fellows, and 3 were non-Contributing Fellows.

On the other hand, 4 Fellows compounded in 1894 for their Annual Contributions, and 1 previously non-Resident Fellow was placed on the Contributing List. The total accession of Contributing Fellows is thus seen to be 40, and the total loss being 45 (19+13+13), the decrease in the number of Contributing Fellows is 5.

During the past year the work has been undertaken of carefully

checking the exact number of Fellows, both by the List and the books, as the growth in the number of non-Contributors concerning whom no information was forthcoming had, apparently for many years past, constituted a great drawback in compiling the annual statistics. The result of this systematic checking shows that, at the end of 1894, the total number of Fellows, Foreign Members, and Foreign Correspondents was 1321, 305 of these being Compounders, 862 Contributing Fellows, 75 non-Contributing Fellows, 40 Foreign Members, and 39 Foreign Correspondents.

At the end of 1893 the Council reported two vacancies in the List of Foreign Correspondents. In 1894 3 Foreign Members and 1 Foreign Correspondent died. During that year, however, 3 Foreign Members and 5 Foreign Correspondents were elected, leaving at the end of the twelvemonth yet one vacancy in the List of Foreign Correspondents.

Turning now to the usual Summary of the Society's Income and Expenditure, the Council have to state that the total Receipts during 1894 amounted to £2643 5*s*. 10*d*., being £96 10*s*. 4*d*. more than the estimated Income, while the total Expenditure in the same period amounted to £2656 2*s*. 8*d*., exceeding the estimated Expenses by £171 5*s*. 4*d*., and the actual Income by £12 16*s*. 10*d*. In accordance with Section XIII. of the Bye-Laws, art. 24, this Meeting is requested to give its sanction to this small excess of Expenditure.

The Council would not have had occasion to report even this small excess of Expenditure over Income, had not an unforeseen expenditure of £96 7*s*. been necessarily incurred for the new boiler connected with the heating apparatus at the Society's Apartments. Until well past the middle of the Session of 1894 there had been no reason for inferring that this expenditure would become necessary.

In their last Annual Report the Council stated their opinion that the time had arrived when the question of safeguarding by investment the interests of Compounders might be reopened.

This led to the appointment of a Finance Committee, which held many sittings, and received much assistance from the statistics carefully compiled by one of your Vice-Presidents, Dr. G. J. Hinde. After long and careful deliberation the Committee came to the conclusion that the Composition Fee should be raised to £35, as from November 1st, 1894; and the Council, and subsequently the Fellows at a Special General Meeting, endorsed this conclusion.

The Council announce with regret the resignation of the Treasurer, Prof. Wiltshire, who for thirteen years has carefully watched over the Society's finances and husbanded its resources.

In announcing the completion of Volume L. of the Society's Quarterly Journal and the commencement of Volume LI., the Council have further to state that the List of Additions to the Library will no longer appear as a part of the Journal. It will be printed annually and distributed to the Fellows as a separate publication, and in such a form that its usefulness will be much enhanced. It will consist of a list of titles under authors' names, supplemented by a classified index of subjects and localities. The Council expect that the first

number of this annual Record will appear concurrently with the May number of the Quarterly Journal; but it is intended that in future years the annual Record shall be distributed at the same time as the February number of the Journal.

The Council had hoped that the Index to the first fifty volumes of the Quarterly Journal would be issued to the Fellows during the present year; but the work has proved arduous beyond anticipation, and it is now evident that the Index cannot be completed until 1896. Every effort, however, will be made to expedite the work, so as to place the Index as soon as may be in the hands of the Fellows.

The following awards of Medals and Memorial Funds have been made by the Council:—

The Wollaston Medal is unanimously awarded to Sir Archibald Geikie, F.R.S., in recognition of his long and brilliant services in the cause of Geological Science.

The Murchison Medal, together with a sum of Ten Guineas from the Proceeds of the Fund, is awarded to Prof. Gustav Lindström, For.Memb. G.S., in recognition of the value of his work upon the organisms of the older rocks.

The Lyell Medal, together with a sum of Thirty-five Pounds from the Proceeds of the Fund, is awarded to the Rev. J. F. Blake, F.G.S., in testimony of appreciation of his work amongst the Jurassic rocks and upon fossil Cephalopoda.

The Bigsby Medal is awarded to Dr. C. D. Walcott, in recognition of the value of his work amongst the older rocks, especially those of North America.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Mr. W. W. Watts, F.G.S., in token of appreciation of his work amongst the older rocks of the Welsh Borders and other districts, and in view of assisting him in the further prosecution of his researches.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mr. A. C. Seward, F.G.S., as a testimony of appreciation of the value of his palæobotanical work, and with the view of assisting him in further research.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Percy F. Kendall, F.G.S., as a testimony of the value of his observations upon the newer deposits, and for the purpose of aiding him in the further prosecution of his researches.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. B. Harrison, of Ightham, in token of appreciation of his work amongst the newer deposits, and to aid him in further research.

Report of the Library and Museum Committee for 1894.

Library.

Your Committee have pleasure in congratulating the Society on the extensive and valuable additions made to the Library during the year under review.

By Donation the Library has received about 125 Volumes of separately published works, 1199 Pamphlets and detached Parts of works, 247 Volumes and 112 detached Parts of the publications of various Societies, Public Bodies, and Government institutions. To these must be added 16 Volumes of Newspapers, making therefore the total accession of books to the Society's Library by Donation amount to 388 Volumes and 1311 Pamphlets and detached Parts. Moreover, 89 Sheets of Maps and 150 Photographs representing landscapes of geological interest have been presented to the Library. The photographic views the Society owes largely to the liberality of Mr. James Jackson, Honorary Librarian of the Geographical Society of France, and to Mr. J. H. Cooke, lately of Malta. Your Committee would also draw attention to the presentation by M. Delebecque of two successive editions of his fine Atlas of the French Lakes.

A very large number of pamphlets from the libraries of Sir John Evans, the Rev. J. F. Blake, and the late Mr. W. Topley have recently enriched the shelves of the Society's Library.

The Books, Maps, and Photographs enumerated above were the gift of 163 Personal Donors, 55 Public Bodies, and 179 Societies and Editors of Periodicals. A detailed List of these is appended to the present Report: and herein your Committee revert to an old custom which had remained in abeyance for many years.

The Purchases made on the recommendation of the Standing Library Committee amounted to 87 Volumes of separately published works, 210 Volumes and 32 Parts of works published serially, and 17 Sheets of Maps.

Further progress has been made during the past year towards the completion of sets of serials in the Library which had long been deficient. Among the most important of these may be mentioned the Abhandlungen of the Prussian Geological Survey, the Memoirs of the Italian Geological Survey, the Matériaux pour la Carte de la Russie, the Saxon Jahrbuch für das Berg- u. Hüttenwesen, the Abhandlungen of the Halle Natural History Society, the Transactions of the Iron and Steel Institute, and the Proceedings of the Somerset Archæological and Natural History Society.

Your Committee have much satisfaction in stating that the manuscript Card Catalogue of the Geological Maps and Sections in the Library, the inception of which was announced last year, is now nearly completed.

The total amount expended upon the Library in the twelvemonth under review is as follows:—

	£	s.	d.
Books, Periodicals, etc., purchased	186	17	4
Binding of Books and Mounting of Maps....	135	9	3
Part cost of preparing Map Catalogue	8	11	0
Total	£330	17	7

Your Committee call attention to the exceptional sum expended during the year upon binding of books and mounting of maps and the completion of sets of serials, and point out that a similar expenditure will not be required during the coming year.

The Society's collection of the portraits of eminent workers in the science of Palæontology has been enriched by the donation of an engraving of the late Sir Richard Owen (presented by Mr. E. Swain), and a photographic portrait of the late J. W. Davis (presented by the Yorkshire Geological and Polytechnic Society).

Museum.

No additions have been made to the collections during the past year.

Mr. C. Davies Sherborn has actively continued the work of labelling and registering the type- and other important specimens, and has completed it so far as the British Collection is concerned. During 1894 he examined the contents of 421 drawers, 142 of which form the Sharp Collection: from these and larger specimens in the Museum he registered altogether 3000 numbers. This useful work, in the opinion of your Committee, should be continued on the Foreign Collection so soon as the available funds of the Society will allow of a grant being made for that purpose.

The expenditure in the Museum during 1894 was as follows:—

	£	s.	d.
Special work (registration, etc.)	42	18	0
Sundries	2	11	6
Total	£45	9	6

The following Lists contain the Names of Government Departments, Public Bodies, Societies and Editors, from whom Donations to the Library have been received during the year 1894:—

I. Government Departments and other Public Bodies.

American Museum of Natural History. New York.
Arkansas Geological Survey. Little Rock.
Austria.—Kaiserlich-Königliche Geologische Reichsanstalt. Vienna.
——. Kaiserlich-Königlich Naturhistorisches Hofmuseum. Vienna.
Bavaria.—Königlich Bayerisches Oberbergamt. Munich.
Bohemia.—Landesdurchforschungs-Comité. Prague.
——. Musée Bohême. Prague.
California.—State Mining Bureau. Sacramento.
Canada.—Geological & Natural History Survey. Ottawa.
Costa Rica.—Museo Nacional de la República de Costa Rica. San José.
Egypt.—Ministry of Public Works. Cairo.
Finland.—Finlands Geologiska Undersökning. Helsingfors.
France.—Dépôt de la Marine. Paris.
——. Ministère des Travaux Publics. Paris.
——. Muséum d'Histoire Naturelle. Paris.
——. Service de la Carte Géologique. Paris.
Great Britain.—Army Medical Department. London.
——. British Museum (Natural History). London.
——. Geological Survey. London.
——. Home Office. London.
Hesse.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Darmstadt.
Holland.—Departement van Kolonien. The Hague.
Illinois.—State Museum of Natural History. Springfield.
India.—Geological Survey. Calcutta.
Italy.—Reale Comitato Geologico d'Italia. Rome.
Japan.—Geological Survey. Tokio.
La Plata Museum. La Plata.
Minnesota.—Geological and Natural History Survey. Minneapolis.
New South Wales.—Agent-General for, London.
——. Australian Museum. Sydney.
——. Department of Lands. Sydney.
——. Department of Mines. Sydney.
——. Geological Survey. Sydney.
New York State Museum. Albany.
New Zealand.—Department of Mines. Wellington, N.Z.
Norway.—Committee of the North-Atlantic Expedition. Christiania.
Portugal.—Direction des Travaux Géologiques du Portugal. Lisbon.
Prussia.—Königlich Preussische Geologische Landesanstalt. Berlin.
——. Ministerium für Handel und Gewerbe. Berlin.
Queensland.—Geological Survey. Brisbane.
Rio de Janeiro.—Museu Nacional. Rio de Janeiro.
Russia.—Comité Géologique. St. Petersburg.
São Paulo.—Commissão Geographica e Geologica. São Paulo.
Saxony.—Geologische Landesuntersuchung des Königreichs Sachsen. Leipzig.
——. Königliches Finanz-Ministerium. Leipzig.
South Australia.—The Agent-General for, London.
Spain.—Comision del Mapa Geologico. Madrid.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Commission der Geologischen Karte. Berne.
United States Geological Survey. Washington.
United States National Museum. Washington.
Victoria.—Department of Mines. Melbourne.
Washington (D. C.).—Smithsonian Institution.
Western Australia.—Geological Survey. Perth.
——. The Agent-General for, London.

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Alnwick.—Berwickshire Naturalists' Club.
Barnsley (Newcastle-upon-Tyne).—Midland Institute of Mining, Civil and Mechanical Engineers.
Basel.—Schweizerische Naturforschende Gesellschaft.
Bath Natural History and Antiquarian Field Club.
Belfast Natural History and Philosophical Society.
Berkeley (Cal.).—Department of Geology, University of California.
Berlin.—Deutsche Geologische Gesellschaft.
——. Gesellschaft Naturforschender Freunde.
——. Königlich Preussische Akademie der Wissenschaften.
Berne.—Allgemeine Schweizerische Gesellschaft für die Gesammten Naturwissenschaften.
——. Naturforschende Gesellschaft.
Birmingham.—Philosophical Society.
Bombay Branch of the Royal Asiatic Society.
Bordeaux.—Société Linnéenne.
Boston (Mass.).—American Academy of Arts and Sciences.
Brunswick.—Verein für Naturwissenschaften.
Brussels.—Société Belge de Géologie, de Paléontologie et d'Hydrologie.
——. Société Malacologique de Belgique.
Budapest.—Magyar Földtani Tarsulat.
Buenos Aires.—Instituto Geografico Argentino.
——. Sociedad Cientifica Argentina.
Caen.—Société Linnéenne de Normandie.
Calcutta.—Indian Engineering.
——. Asiatic Society of Bengal.
Cambridge.—Philosophical Society.
Cambridge (Mass.).—Museum of Comparative Zoology, at Harvard College.
Cape Town.—South African Philosophical Society.
Cardiff.—South Wales Institute of Engineers.
Chicago.—Journal of Geology.
Cincinnati Society of Natural History.
Colombo.—Ceylon Branch of the Royal Asiatic Society.
Copenhagen.—Kongelige Danske Videnskabernes Selskab.
——. Universitets Zoologiske Museum.
Córdoba (Argentine Republic).—Academia Nacional de Ciencias.
Cracow.—Akademja Umiejetosci.
Darmstadt.—Verein für Erdkunde.
Davenport (Iowa).—Academy of Natural Science.
Dijon.—Académie des Sciences, Arts et Belles-Lettres.
Douglas.—Isle of Man Natural History and Antiquarian Society.
Dresden.—Naturwissenschaftliche Gesellschaft 'Isis.'
——. Verein für Erdkunde.
Dublin.—Royal Irish Academy.
Edinburgh Geological Society.
——. Royal Physical Society.
——. Royal Scottish Geographical Society.
——. Royal Society.
Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.
Falmouth.—Royal Cornwall Polytechnic Society.
Frankfurt a. M.—Senckenbergische Naturforschende Gesellschaft.
Freiburg i. B.—Naturforschende Gesellschaft.
Geneva.—Société de Physique et d'Histoire Naturelle.
Giessen.—Oberhessische Gesellschaft für Natur- und Heilkunde.
Gloucester.—Cotteswold Naturalists' Field-Club.
Haarlem.—Société Hollandaise des Sciences.
Halifax.—Yorkshire Geological and Polytechnic Society.
Halifax, N. S.—Nova Scotian Institute of Science.
Halle.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
Hamilton (Canada).—Hamilton Association.
Havre.—Société Géologique de Normandie.
Helsingfors.—Société de Géographie de Finlande.

Hermannstadt.—Siebenbürgischer Verein für Naturwissenschaften.
Hertford.—Hertfordshire Natural History Society.
Hobart.—Royal Society of Tasmania.
Houghton (Mich.).—Michigan Mining School.
Kingston (Canada).—Queen's College.
Lausanne.—Société Géologique Suisse.
——. Société Vaudoise des Sciences Naturelles.
Leicester Literary and Philosophical Society.
Leipzig.—Zeitschrift für Krystallographie und Mineralogie.
——. Zeitschrift für Naturwissenschaften.
Liége.—Société Géologique de Belgique.
Lille.—Société Géologique du Nord.
Lisbon.—Sociedade de Geographia.
Liverpool.—Geological Society.
London.—Academy.
——. Athenæum.
——. British Association for the Advancement of Science.
——. Chemical News.
——. Chemical Society.
——. Colliery Guardian.
——. East India Association.
——. Geological Magazine.
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Iron and Steel Institute.
——. Iron and Steel Trades' Journal.
——. Linnean Society.
——, Edinburgh, and Dublin Philosophical Magazine.
——. Mineralogical Society.
——. Nature.
——. Palæontographical Society.
——. Physical Society.
——. Royal Agricultural Society.
——. Royal Asiatic Society.
——. Royal College of Surgeons.
——. Royal Geographical Society.
——. Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society of Great Britain.
——. Royal Society.
——. Sanitary Institute.
——. Science and Art.
——. Society of Arts.
——. Society of Biblical Archæology.
——. Society of Public Analysts.
——. University College.
——. Victoria Institute.
——. Zoological Society.
Madison (Wis.).—Wisconsin Academy of Sciences.
Manchester Geological Society.
——. Literary and Philosophical Society.
Melbourne.—Royal Society of Victoria.
Mexico.—Sociedad Mexicana de Historia Natural.
Milan.—Giornale di Mineralogia.
——. Società Italiana di Scienze Naturali.
Minneapolis.—American Geologist.
Montreal.—Natural History Society.
Moscow.—Société Impériale des Naturalistes.
Munich.—Königlich Bayerische Akademie der Wissenschaften.
Nancy.—Académie de Stanislas.
Newcastle-under-Lyme.—North Staffordshire Institute of Mining and Mechanical Engineers.
Newcastle-upon-Tyne.—Durham College of Science.
——. Natural History Society of Northumberland and Durham.
——. North of England Institute of Mining and Mechanical Engineers.
New Haven (Conn.).—American Journal of Science.

New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
Northampton.—Northamptonshire Natural History Society.
Oporto.—Sociedade Carlos Ribeiro.
Ottawa.—Royal Society of Canada.
Padua.—Reale Accademia di Scienze, Lettere, ed Arti.
Paris.—Académie des Sciences.
——. Annuaire Géologique Universel.
——. Revue Scientifique.
——. Société Française de Minéralogie.
——. Société Géologique de France.
Penzance.—Royal Geological Society of Cornwall.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
Pisa.—Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
Port-of-Spain.—Victoria Institute of Trinidad.
Rochester (N. Y.).—Geological Society of America.
Rome.—Reale Accademia dei Lincei.
——. Società Geologica Italiana.
Rugby School Natural History Society.
St. John (N. B.).—Natural History Society.
St. Petersburg.—Académie Impériale des Sciences.
——. Russisch Kaiserliche Mineralogische Gesellschaft.
Santiago.—Deutscher Wissenschaftlicher Verein.
——. Société Scientifique du Chili.
Scranton, Pa.—Colliery Engineer.
Shanghai.—China Branch of the Royal Asiatic Society.
Sherborne.—Dorset Natural History and Antiquarian Field-Club.
Stockholm.—Geologiska Förening.
——. Kongliga Svenska Vetenskaps Akademi.
Stuttgart.—Neues Jahrbuch für Mineralogie, Geologie und Paläontologie.
——. Verein für Vaterländische Naturkunde in Württemberg.
Sydney.—Australasian Association for the Advancement of Science.
——. Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Tokyo.—College of Science, Imperial University.
——. Imperial University.
——. Seismological Journal of Japan.
Topeka (Kan.).—Kansas Academy of Science.
Toronto.—Canadian Institute.
Tufts College, Mass.
Turin.—Reale Accademia delle Scienze.
Vienna.—Berg- und Hüttenmännisches Jahrbuch.
——. Kaiserliche Akademie der Wissenschaften.
——. Kaiserlich Königliche Zoologisch-botanische Gesellschaft.
——. Mineralogische und Petrographische Mittheilungen.
Wellington (N.Z.).—New Zealand Institute.
Wiesbaden.—Nassauischer Verein für Naturkunde.
York.—Natural History Journal.
——. Yorkshire Philosophical Society.

III. Personal Donors.

Abbott, W. J. L.
Alfaro, A.
Ameghino, F.
Andersson, J. G.

Barbour, E. H.
Barlow, W.
Bather, F. A.
Bauerman, H.
Bayley, W. S.
Beecher, C. E.
Belinfante, L. L.
Bell, D.
Bertrand, C. E.
Bertrand, M.
Bittner, A.
Blake, J. F.
Blake, W. P.
Branco, W.
Branner, J. C.
Briart, A.
Brodie, P. B.
Brown, H. Y. L.
Buckman, S. S.
Calderon, S.
Calvin, V.
Carey, L.
Cayeux, L.
Chewings, C.
Clark, W. B.
Coghlan, T. A.
Collins, J. H.
Cooke, J. H.
Cotteau, G.
Credner, H.

Dames, W.
Davis, W. M.
Dawson, G. M.
Dawson, Sir J. W.
Dewalque, G.
Dollfus, G. F.
Draper, D.
Drayson, A. W.
Dubois, E.
Dunn, E. J.
Dupare, L.

Egger, J. G.
Ettingshausen, C. Frh. von.
Evans, Sir John.

Farrington, O. C.
Favre, E.
Felix, J.
Fisher, O.
Fornasini, C.
Foster, C. Le Neve.
Fox, H.
Francis, W.
Fritsch, A.

Garland, J.
Gilpin, E., Jun.
Gosselet, J.
Guppy, R. L.

Harker, Alfred.
Harle, E.
Harris, G. F.
Haugh, H.
Hicks, H.
Hobson, G.
Howorth, Sir Henry H.
Hull, E.
Hume, W. F.
Hutchinson, H. N.

Iddings, J. P.

Jack, R. L.
Jackson, J.
Johnston, R. M.
Johnston-Lavis, H. J.
Jones, D.
Jones, T. R.
Jukes-Browne, A. J.

Karrer, F.
Kirkby, J. W.
Koenen, A. von.
Kossmat, F.
Krustschoff, K. von.
Kurtz, F.

Lacroix, A.
Lapparent, A. de.
Lapworth, C.
Lévy, A. Michel.
Lewis, Mrs. Carvill.
Liversidge, A.
Lord, E. C. E.
Lyman, B. S.

McKay, A.
Mansel-Pleydell, J. C.
Marsh, O. C.
Meli, R.
Merrill, G. P.
Millar, C. C. H.
Monckton, H. W.
Morton, G. H.
Mrazec, L.
Munby, A. E.
Murray, J.

Nathorst, A. G.
Newton, E. T.
Newton, R. B.

Oldham, R. D.
Omboni, G.

Palache, C.
Parent, H.
Pasquier, L. du.
Peralta, M. de.
Petersen, C. G. J.
Poole, H. S.
Pompeckj, J. F.
Portis, A.
Power, F. D.
Preller, C. S. Du Riche.
Prestwich, J.
Quareña, F.
Quiraga, F.

Reade, T. M.
Renard, A. F.
Renault, B.
Renevier, E.
Richards, Sir G. H.
Ritter, E.
Rutley, F.

Sacco, F.
Sandberger, F. von.
Sauvage, H. E.
Sawyer, A. R.
Schardt, H.
Scharff, R. F.
Schenk, A.
Scudder, S. H.
Seeley, H. G.
Senft, Frau Geh. Hofrath Jeannette.
Sherborn, C. D.
Shone, W.
Sieger, R.
Smith, E. A.
Smith, P. W. B.
Spencer, J. W.

Tate, R.
Tate, T.
Thompson, B.
Topley, Mrs. W.
Traverso, S.

Van den Broeck, E.

Wadsworth, M. E.
Watts, W. W.
Welch, R.
Whitaker, W.
Whitney, J. D.
Williams, G. H.
Wilson, E.
Woodward, A. S.
Woodward, H.
Woodward, H. B.
Woodward, H. P.
Wray, L., Jun.

STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEAR 1894.

Compounders	305
Contributing Fellows	862
Non-contributing Fellows	75
	1242
Foreign Members	40
Foreign Correspondents	39
	1321

Comparative Statement explanatory of the Alterations in the Number of Foreign Members and Foreign Correspondents at the close of the years 1893 *and* 1894.[1]

Number of Foreign Members and Foreign Correspondents, December 31st, 1893		78
Deduct Foreign Members deceased	3	
Foreign Correspondent deceased	1	
Foreign Correspondents elected Foreign Members	3	
	—	7
		71
Add Foreign Members elected		3
Foreign Correspondents elected		5
		79

[1] The Comparative Statement of the number of *Fellows* is not given this year. As already stated in the Report of the Council, the number has been checked with the List and books, and, not being found to agree with that previously printed, has been corrected as above.

Deceased Fellows.

Compounders (4).

Arden, R. E., Esq.
Humiston, Prof. R. F.
Ibbetson, G. A., Esq.
Stoddart, J., Esq.

Resident and other Contributing Fellows (13).

Birds, J. A., Esq.
Fischer, Dr. C.
Hale, Rev. E.
Keller, E., Esq.
Maxted, C., Esq.
Morgan, J. B., Esq.
Murray, A., Esq.
Plant, Major J.
Schute, F., Esq.
Swansea, Lord.
Topley, W., Esq.
Tuckett, P. D., Esq.
Worsley, P., Esq.

Non-contributing Fellows (3).

Mackeson, H. B., Esq.
Pengelly, W., Esq.
Timmins, C., Esq.

Foreign Members (3).

Beneden, Prof. J. van.
Cotteau, M. G. H.
Szabó, Dr. J.

Foreign Correspondent (1).

Williams, Prof. G. H.

Fellows Resigned (19).

Boam, F. W., Esq.
Bowman, Dr. F. H.
Cleminshaw, E., Esq.
Darbishire, R. D., Esq.
Huxham, H., Esq.
James, Capt. W. H.
Kirkhouse, H., Esq.
Osborn, J. A., Esq.
Pelly, Rev. S. A.
Roberts, P. J., Esq.
Shone, I., Esq.
Smith, Dr. J. T.
Teale, J. W., Esq.
Timins, Rev. J. H.
Vivian, A. P., Esq.
Warton, Lt.-Col. R. G.
West, Rev. G. H.
Wright, G. H. C.
Yorke, P., Esq.

Fellows Removed (15).

*Bradley, L., Esq.
Cowell, W. J. R., Esq.
Dash, T. A., Esq.
Matthews, F. J. A., Esq.
Parker, C., Esq.
Richards, E. M., Esq.
Roberts, Rev. J. C.
Rogers, S., Esq.
Ruscoe, J., Esq.
*Stephen, G. M., Esq.
Swinburne, U. P., Esq.
Taylor, Dr. J. E.
Townsend, T. C., Esq.
Trinks, C. H., Esq.
Truscott, S. J., Esq.

* Removed from the List after having remained thereon for many years without any known address.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1894:—

Professor George J. Brush, of New Haven, Conn., U.S.A.
Professor Edward Salisbury Dana, of New Haven, Conn., U.S.A.
Professor Alphonse Renard, of Ghent.

The following Personages were elected Foreign Correspondents during the year 1894:—

Professor Joseph Paxson Iddings, of Chicago, U.S.A.
Monsieur Perceval de Loriol-Lefort, of Campagne Frontenex.
Doctor Francisco P. Moreno, of La Plata.
Doctor A. Rothpletz, of Munich.
Professor J. H. L. Vogt, of Christiania.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Dr. G. J. Hinde and Prof. J. W. Judd, retiring from the office of Vice-Presidents.

That the thanks of the Society be given to Prof. T. Wiltshire, retiring from the office of Treasurer.

That the thanks of the Society be given to A. Harker, Esq., Prof. C. Lapworth, H. W. Monckton, Esq., C. Reid, Esq., and Prof. T. Wiltshire, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

Henry Woodward, LL.D., F.R.S.

VICE-PRESIDENTS.

Prof. A. H. Green, M.A., F.R.S.
W. H. Hudleston, Esq., M.A., F.R.S.
R. Lydekker, Esq., B.A., F.R.S.
Lieut.-General C. A. M^{c}Mahon.

SECRETARIES.

J. E. Marr, Esq., M.A., F.R.S.
J. J. H. Teall, Esq., M.A., F.R.S.

FOREIGN SECRETARY.

J. W. Hulke, Esq., F.R.S. (*since deceased*).

TREASURER.

W T. Blanford, LL.D., F.R.S.

COUNCIL.

H. Bauerman, Esq.
W. T. Blanford, LL.D., F.R.S.
Prof. W. Boyd Dawkins, M.A., F.R.S.
Sir John Evans, K.C.B., LL.D., F.R.S., F.L.S.
Prof. A. H. Green, M.A., F.R.S.
J. W. Gregory, D.Sc.
R. S. Herries, Esq., M.A.
G. J. Hinde, Ph.D.
T. V. Holmes, Esq.
W. H. Hudleston, Esq., M.A., F.R.S., F.L.S.
J. W. Hulke, Esq., F.R.S. (*since deceased*).
Prof. J. W. Judd, F.R.S.
R. Lydekker, Esq., B.A., F.R.S.
Lieut.-General C. A. M^{c}Mahon.
J. E. Marr, Esq., M.A., F.R.S.
H. A. Miers, Esq., M.A.
E. T. Newton, Esq., F.R.S.
F. Rutley, Esq.
J. J. H. Teall, Esq., M.A., F.R.S.
W. Whitaker, Esq., B.A., F.R.S.
Rev. H. H. Winwood, M.A.
Henry Woodward, LL.D., F.R.S.
H. B. Woodward, Esq.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1894.

Date of Election.

1848. James Hall, Esq., *Albany, State of New York, U.S.A.*
1851. Professor James D. Dana, *New Haven, Connecticut, U.S.A.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. B. Geinitz, *Dresden.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. M. Jules Marcou, *Cambridge, U.S.A.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1882. Professor Sven Lovén, *Stockholm.*
1882. Professor Ludwig Rütimeyer, *Basel.*
1883. Professor Otto Martin Torell, *Stockholm.*
1884. Professor G. Capellini, *Bologna.*
1884. Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1884. Professor J. Szabó, *Pesth.* (*Deceased.*)
1885. Professor Jules Gosselet, *Lille.*
1886. Professor Gustav Tschermak, *Vienna.*
1887. Professor J. P. Lesley, *Philadelphia, U.S.A.*
1887. Professor J. D. Whitney, *Cambridge, U.S.A.*
1888. Professor Pierre J. van Beneden, *Louvain.* (*Deceased.*)
1888. Professor Eugène Renevier, *Lausanne.*
1888. Baron Ferdinand von Richthofen, *Berlin.*
1889. Professor Ferdinand Fouqué, *Paris.*
1889. Marquis Gaston de Saporta, *Aix-en-Provence.* (*Deceased.*)
1889. Geheimrath Professor Karl Alfred von Zittel, *Munich.*
1890. Professor Heinrich Rosenbusch, *Heidelberg.*
1891. Dr. Charles Barrois, *Lille.*
1891. M. Gustave H. Cotteau, *Auxerre.* (*Deceased.*)
1892. Professor Gustav Lindström, *Stockholm.*
1893. Professor Waldemar Christofer Brögger, *Christiania.*
1893. M. Auguste Michel-Lévy, *Paris.*
1893. Dr. Edmund Mojsisovics von Mojsvár, *Vienna.*
1893. Dr. Alfred Gabriel Nathorst, *Stockholm.*
1894. Professor George J. Brush, *New Haven, Conn., U.S.A.*
1894. Professor Edward Salisbury Dana, *New Haven, Conn., U.S.A.*
1894. Professor Alphonse Renard, *Ghent.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1894.

Date of Election.	
1866.	Professor Victor Raulin, *Montfaucon d'Argonne.*
1874.	Professor Igino Cocchi, *Florence.*
1874.	Dr. T. C. Winkler, *Haarlem.*
1879.	M. Édouard Dupont, *Brussels.*
1879.	Dr. Émile Sauvage, *Boulogne-sur-Mer.*
1881.	Professor E. D. Cope, *Philadelphia, U.S.A.*
1882.	Professor Louis Lartet, *Toulouse.*
1882.	Professor Alphonse Milne-Edwards, *Paris.*
1884.	M. Alphonse Briart, *Morlanwelz.*
1884.	Professor Hermann Credner, *Leipzig.*
1884.	Baron C. von Ettingshausen, *Grätz.*
1887.	Senhor J. F. N. Delgado, *Lisbon.*
1887.	Professor A. Heim, *Zürich.*
1887.	Professor A. de Lapparent, *Paris.*
1888.	M. Charles Brongniart, *Paris.*
1888.	Professor Anton Fritsch, *Prague.*
1888.	M. Ernest Van den Broeck, *Brussels.*
1889.	Professor G. K. Gilbert, *Washington, D.C., U.S.A.*
1889.	Dr. Hans Reusch, *Christiania.*
1889.	M. R. D. M. Verbeek, *Padang, Sumatra.*
1890.	M. Gustave F. Dollfus, *Paris.*
1890.	Herr Felix Karrer, *Vienna.*
1890.	Professor Adolph von Könen, *Göttingen.*
1890.	M. Friedrich Schmidt, *St. Petersburg.*
1891.	Señor Don Antonio del Castillo, *Mexico.*
1891.	Professor W. Dames, *Berlin.*
1891.	Professor Emanuel Kayser, *Marburg.*
1892.	Professor Johann Lehmann, *Kiel.*
1892.	Major John W. Powell, *Washington, D.C., U.S.A.*
1892.	Professor George H. Williams, *Baltimore, U.S.A.* (*Deceased.*)
1893.	Professor Marcel Bertrand, *Paris.*
1893.	Professor Aléxis Pavlow, *Moscow.*
1893.	M. Ed. Rigaux, *Boulogne-sur-Mer.*
1893.	Dr. Sven Leonhard Törnquist, *Lund.*
1893.	Dr. Charles Abiathar White, *Washington, D.C., U.S.A.*
1894.	Professor Joseph Paxson Iddings, *Chicago, U.S.A.*
1894.	M. Perceval de Loriol-Lefort, *Campagne Frontenex.*
1894.	Dr. Francisco P. Moreno, *La Plata.*
1894.	Dr. A. Rothpletz, *Munich.*
1894.	Professor J. H. L. Vogt, *Christiania.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. Louis Agassiz.
1837. Capt. T. P. Cautley. Dr. H. Falconer.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. M. Élie de Beaumont. M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. M. le Vicomte A. d'Archiac. M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. Herr Hermann von Meyer. Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Sir A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. W. T. Blanford.
1884. Professor Albert Gaudry.
1885. Mr. George Busk.
1886. Professor A. L. O. Des Cloizeaux.
1887. Mr. J. Whitaker Hulke.
1888. Mr. H. B. Medlicott.
1889. Professor T. G. Bonney.
1890. Professor W. C. Williamson.
1891. Professor J. W. Judd.
1892. Baron Ferdinand von Richthofen.
1893. Professor N. S. Maskelyne.
1894. Geheimrath Professor Karl Alfred von Zittel.
1895. Sir Archibald Geikie.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON 'DONATION FUND.'

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. / M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Dr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Dr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. / Mr. W. K. Parker.
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Dr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Professor John Milne.
1884. Mr. E. Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. S. Gardner.
1887. Mr. B. N. Peach.
1888. Mr. J. Horne.
1889. Mr. A. Smith Woodward.
1890. Mr. W. A. E. Ussher.
1891. Mr. R. Lydekker.
1892. Mr. O. A. Derby.
1893. Mr. J. G. Goodchild.
1894. Mr. Aubrey Strahan.
1895. Mr. W. W. Watts.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Professor H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Dr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Rev. J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor Charles Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Sir Archibald Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal.*
1882. Professor T. Rupert Jones.
1883. Professor H. R. Göppert. *Medal.*
1883. Mr. John Young.
1884. Dr. H. Woodward. *Medal.*
1884. Mr. Martin Simpson.
1885. Dr. Ferdinand von Römer. *Medal.*
1885. Mr. Horace B. Woodward.
1886. Mr. W. Whitaker. *Medal.*
1886. Mr. Clement Reid.
1887. Rev. P. B. Brodie. *Medal.*
1887. Mr. Robert Kidston.
1888. Professor J. S. Newberry. *Medal.*
1888. Mr. Edward Wilson.
1889. Professor James Geikie. *Medal.*
1889. Professor G. A. J. Cole.
1890. Professor Edward Hull. *Medal.*
1890. Mr. E. Wethered.
1891. Professor W. C. Brögger. *Medal.*
1891. Rev. R. Baron.
1892. Professor A. H. Green. *Medal.*
1892. Mr. Beeby Thompson.
1893. Rev. O. Fisher. *Medal.*
1893. Mr. G. J. Williams.
1894. Mr. W. T. Aveline. *Medal.*
1894. Mr. George Barrow.
1895. Professor Gustav Lindström. *Medal.*
1895. Mr. A. C. Seward.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE 'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Professor W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Sir John Evans. *Medal.*
1880. Professor F. A. von Quenstedt.
1881. Sir J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor Charles Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor Charles Lapworth.
1885. Professor H. G. Seeley. *Medal.*
1885. Mr. A. J. Jukes-Browne.
1886. Mr. W. Pengelly. *Medal.*
1886. Mr. D. Mackintosh.
1887. Mr. Samuel Allport. *Medal.*
1887. Rev. Osmond Fisher.
1888. Professor H. A. Nicholson. *Medal.*
1888. Mr. A. H. Foord.
1888. Mr. Thomas Roberts.
1889. Professor W. Boyd Dawkins. *Medal.*
1889. M. Louis Dollo.
1890. Professor T. Rupert Jones. *Medal.*
1890. Mr. C. Davies Sherborn.
1891. Professor T. McKenny Hughes. *Medal.*
1891. Dr. C. J. Forsyth-Major.
1891. Mr. G. W. Lamplugh.
1892. Mr. G. H. Morton. *Medal.*
1892. Dr. J. W. Gregory.
1892. Mr. E. A. Walford.
1893. Mr. E. T. Newton. *Medal.*
1893. Miss C. A. Raisin.
1893. Mr. A. N. Leeds.
1894. Professor John Milne. *Medal.*
1894. Mr. William Hill.
1895. Rev. J. F. Blake. *Medal.*
1895. Mr. P. F. Kendall.
1895. Mr. B. Harrison.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Professor Alphonse Renard.
1887. Professor Charles Lapworth.
1889. Mr. J. J. Harris Teall.
1891. Dr. George M. Dawson.
1893. Professor W. J. Sollas.
1895. Dr. C. D. Walcott.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
1881. Purchase of microscope lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Professor Charles Mayer-Eymar.
1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1894. Mr. Charles Davison.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions				101	10	0
Due for Arrears of Admission-fees	50	8	0			
Admission-fees, 1895	189	0	0			
				239	8	0
Due for Arrears of Annual Contributions				105	0	0
Annual Contributions, 1895, from Resident Fellows, and Non-residents, 1859 to 1861				1610	0	0
Annual Contributions in advance				35	0	0
Dividends on Consolidated $2\frac{3}{4}$ per Cents.				100	4	0
Dividends on London and North-Western Railway 4 per cent. Consolidated Preference Stock				87	3	8
Dividends on London and South-Western Railway 4 per cent. Preference Stock				108	10	0
Dividends on London, Brighton, and South Coast Railway 5 per cent. Consolidated Preference Stock				14	10	8
Sale of Quarterly Journal, including Longman's account	165	0	0			
Sale of Geological Map, including Stanford's account	12	0	0			
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's 'New Zealand,' and List of Fellows	5	0	0			
				182	0	0
				£2583	6	4

THOMAS WILTSHIRE, TREASURER.

9th January, 1895.

the Year 1895.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	3	15	0			
Fire-insurance	15	0	0			
Gas	25	0	0			
Fuel	30	0	0			
Furniture and Repairs	35	0	0			
House-repairs and Maintenance	30	0	0			
Annual Cleaning	15	0	0			
Washing and Sundries	25	0	0			
Tea at Meetings	15	0	0			
				193	15	0
Salaries and Wages, etc.:						
Assistant Secretary	250	0	0			
„ Half premium of Life Insurance	10	15	0			
Assistant Librarian and Assistant Clerk	270	0	0			
House Porter and Upper-Housemaid, including Uniform and Allowance for Washing	91	12	0			
Under-Housemaid, including Allowance for Washing	42	12	0			
Errand Boy	28	12	0			
Charwoman and Occasional Assistance	12	0	0			
Accountant's Fee	10	10	0			
				716	1	0
Official Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	35	0	0			
Postages and other Expenses	85	0	0			
				145	0	0
Library (Books and Binding)				250	0	0
Museum				50	0	0
Publications:						
Geological Map	10	0	0			
Quarterly Journal	850	0	0			
„ „ Commission, Postage, and Addressing	95	0	0			
*Index to Quarterly Journal [Vols. 1–50]	75	0	0			
Record of Current Geological Literature	50	0	0			
List of Fellows	35	0	0			
Abstracts, including Postage	110	0	0			
				1225	0	0
Balance in favour of the Society				3	10	4
				£2583	6	4

*. This is a portion of the sum of £450 sanctioned for preparing an Index to the Quarterly Journal.

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January, 1894	356	1	2			
Balance in Clerk's hands, 1 January, 1894	15	4	9			
				371	5	11
Compositions				105	0	0
Arrears of Admission-fees	44	2	0			
Admission-fees, 1894	226	16	0			
				270	18	0
Arrears of Annual Contributions				103	19	0
Annual Contributions for 1894, viz.:						
Resident Fellows	1592	17	0			
Non-Resident Fellows	14	3	6			
				1607	0	6
Annual Contributions in advance				44	2	0
Dividends on $2\frac{3}{4}$ p. c. Consolidated Stock	100	8	7			
,, L. & N. W. Railway Stock	87	5	7			
,, L. & S. W. Railway Stock	108	12	4			
,, L. B. & S. C. Railway Stock	14	11	0			
				310	17	6
Taylor & Francis: Advertisements in Journal, Vol. 49					8	6
Publications:						
Sale of Journal, Vols. 1–49	90	15	10			
,, Vol. 50 *	75	13	9			
Sale of Library Catalogue		15	0			
Sale of Geological Map †	22	1	9			
Sale of Ormerod's Index		2	0			
Sale of Hochstetter's 'New Zealand'		2	0			
Sale of Transactions	1	18	0			
Sale of List of Fellows		12	0			
				192	0	4
Repayment of Income Tax under Schedule C for the year 1893–94				9	0	0

*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 50, etc. 61 18 7
†Due from Stanford on account of Geological Map... 6 6 11

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) C. A. McMAHON, F. W. RUDLER, } *Auditors.*

26th January, 1895.

£3014 11 9

Year ending December 31st, 1894.

EXPENDITURE.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	5	8	4			
Fire-insurance	15	0	0			
Gas	21	3	9			
Fuel	22	15	4			
Furniture and Repairs	42	2	0			
House-repairs, Ordinary	25	15	5			
„ Extraordinary	96	7	0			
Annual Cleaning	10	10	6			
Washing and Sundries	17	17	11			
Tea at Meetings	14	10	5			
				271	10	8
Salaries and Wages, etc.:						
Assistant Secretary	250	0	0			
„ Half premium of Life Insurance	10	15	0			
Assistant Librarian and Assistant Clerk	270	0	0			
House Porter and Upper-Housemaid, including Uniform and Allowance for Washing	91	11	9			
Under-Housemaid, including Allowance for Washing	42	12	0			
Errand Boy	26	16	0			
Charwoman and Occasional Assistance	7	5	6			
Accountant's Fee	10	10	0			
				709	10	3
Official Expenditure:						
Stationery	25	12	8			
Miscellaneous Printing	35	14	4			
Postages and other Expenses	77	5	1			
				138	12	1
Library				330	17	7
Museum				45	9	6
Publications:						
Geological Map	7	14	8			
Journal, Vols. 1–49	15	3	1			
„ Vol. 50 905 13 7						
„ „ Commission, Postage, and Addressing 87 6 5						
	993	0	0			
List of Fellows	35	18	4			
Abstracts, including Postage	108	6	6			
				1160	2	7
Balance in Bankers' hands, 31 Dec. 1894	345	1	8			
Balance in Clerk's hands, 31 Dec. 1894	13	7	5			
				358	9	1
THOMAS WILTSHIRE, *Treasurer.*				£3014	11	9

'Wollaston Donation Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1894	22	9	5	Cost of striking Gold Medal awarded to Geheimrath Professor K. A. von Zittel	10	10	0
Dividends on the Fund invested in 2¾ per cent. Consolidated Stock	28	17	6	Award to Mr. A. Strahan	19	4	1
Repayment of one year's Income Tax under Schedule C		17	7	Balance at Bankers', 31 December, 1894	22	10	5
	£52	4	6		£52	4	6

'Murchison Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1894	20	9	2	Award to Mr. W. T. Aveline, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 3 per cent. Debenture Stock	38	16	2	,, Mr. G. Barrow	28	10	8
Repayment of one year's Income Tax under Schedule C	1	2	6	Cost of Medal		17	0
				Balance at Bankers', 31 December, 1894	20	10	2
	£60	7	10		£60	7	10

'Lyell Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1894	53	1	2	Award to Prof. J. Milne, with Medal	46	0	0
Dividends on the Fund invested in Metropolitan 3½ per cent. Stock	68	3	2	,, Mr. W. Hill	23	1	8
Repayment of one year's Income Tax under Schedule C	2	1	0	Cost of Medal	1	1	0
				Balance at Bankers', 31 December, 1894	53	2	8
	£123	5	4		£123	5	4

'Barlow-Jameson Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January, 1894	50	2	9	Award to Mr. C. Davison	25	0	0
Dividends on the Fund invested in 2¾ per cent. Consolidated Stock	13	6	6	Balance at Bankers', 31 December, 1894	38	17	3
Repayment of one year's Income Tax under Schedule C		8	0				
	£63	17	3		£63	17	3

'Bigsby Fund.' Trust Account.

Receipts.	£	s.	d.
Balance at Bankers', 1 January, 1894	4	6	7
Dividends on the Fund invested in 2¾ per cent. Consolidated Stock	5	11	5
Repayment of one year's Income Tax under Schedule C		3	7
	£10	1	7

Payments.	£	s.	d.
Balance at Bankers', 31 December, 1894	10	1	7
	£10	1	7

Valuation of the Society's Property; 31st December, 1894.

Property.	£	s.	d.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. L. etc.				61	18	7
Due from Stanford, on account of Map				6	6	11
Balance in Bankers' hands, 31 Dec. 1894				345	1	8
Balance in Clerk's hands, 31 Dec. 1894				13	7	5
Funded Property:—	£	s.	d.			
Consolidated 2¾ per Cents. at 102	3769	2	6	3844	10	2
London & North-Western Railway 4 per cent. Consolidated Pref. Stock at 140.	2250	0	0	3150	0	0
London & South-Western Railway 4 per cent. Preference Stock at 139	2800	0	0	3892	0	0
London, Brighton, & South Coast Railway 5 per cent. Consolidated Pref. Stock at 172	300	0	0	516	0	0
Arrears of Admission-fees (considered good)				50	8	0
Arrears of Annual Contributions (considered good)				105	0	0
[*N.B.—The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]				£11,984	12	9

THOMAS WILTSHIRE, *Treasurer.*

26th January, 1895.

	£	s.	d.
Balance in favour of the Society	11,984	12	9
	£11,984	12	9

Award of the Wollaston Medal.

In presenting the Wollaston Medal to Sir Archibald Geikie, D.Sc., LL.D., F.R.S.L. & E., F.G.S., the President addressed him as follows:—

Sir Archibald Geikie,—

It is one of the greatest pleasures of my office to be the medium of the Council in conveying to so distinguished a recipient as yourself the Wollaston Medal—the highest token of appreciation which it is within their power to bestow; and to assure you, at the same time, of the unanimity of good will and esteem which marks its presentation.

I find it a most difficult task adequately to express, in a few words, an idea of the great services that you have rendered to Geology, whether as an active worker and observer in the field—for forty years—or as an eloquent and polished literary exponent of the science which we cultivate.

In 1863 you published not the least important of your Memoirs, 'On the Phenomena of the Glacial Drift of Scotland,' in which you gave the earliest connected account of the various Drift-deposits and chief Glacial features of your native country, and you then advocated the agency of land-ice in the formation of the great accumulations of Boulder Clay and Till. This, and the later surface-changes, with their geologic and historic associations, have ever interested you,—and in your 'Scenery of Scotland' you have rendered the subject most instructive and interesting to others also—both by pen and pencil.

The regions of Skye have always had a peculiar fascination for you. In your earliest contribution to this Society you described the subdivisions and enumerated the fossils of the Lias of that Island.

Later on your attention became directed to the Volcanic Rocks of the Inner Hebrides. These researches—which were eventually embodied in your great Memoir on 'The History of Volcanic Action during the Tertiary Period in the British Isles'—will hold a lasting place in geological literature.

You early studied the microscopic structure of rocks—and the eruptive ejectamenta of different periods engaged your attention.

Your Memoir on the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth (1879),—one of the earlier fruits of these

researches,—deserves especial mention; and you were eventually led to consider generally the history of volcanic action in Britain, an account of which is given in the two Presidential Addresses delivered by you before this Society (1891–92). I may also allude to your Memoir on the Old Red Sandstone; to your researches among the older rocks, and to the admirable manner in which you have directed the labours of your staff on the Geological Survey, especially in their work among the Scottish Highlands—where the geologist is confronted by some of the most difficult and complicated of geological problems. Your great Text-Book of Geology; your attractive memoirs of Edward Forbes, of Murchison, and lastly, that just published, of Ramsay—attest the facility with which you wield the pen, as well as the hammer. It has been my good fortune to claim you among my personal friends since first we met in 1864, and many good papers by you have appeared in the Geological Magazine, as well as in the Quarterly Journal. May you long continue to hold the important position of Director-General of our Geological Survey—to the well-being of the members of your staff, and to the advancement of Geology in this country.

Sir Archibald Geikie, in reply, said:—

Mr. President,—

To receive from the Geological Society its highest award, and thus to be enrolled in that list of illustrious names so intimately associated with the birth and progress of Geology, is a distinction of which a man may well be proud. I am deeply grateful to the Council for the honour which they confer upon me, and to you, Sir, for the kindly but too eulogistic words with which you have handed to me the Wollaston Medal. For any services which I have been able to render to the cause of our favourite science I am mainly indebted to the enthusiasm with which, in my boyhood, the science itself inspired me. Geology early fascinated me, and she fascinates me still. She filled me with earnest desire to devote my life to her service, and so overmastering did this desire become that, although destined for a wholly different career, I was finally allowed to follow whither she led. That ardour has lasted ever since, and I am not conscious that it has yet begun to grow dim, even although sometimes one may perhaps feel the hills to be a little steeper and the miles a little longer than they used to be thirty or forty years ago.

But, passing from merely personal considerations, I receive this award with peculiar satisfaction, because I regard it as another link in the chain of mutual kindness and helpfulness which binds together this Society and the Geological Survey. Among the recipients of the Wollaston Medal I find the names of all my predecessors at the head of the Survey. That you should have added my name to the list is doubly gratifying, for it may, I trust, be taken as a proof that the feelings of cordial sympathy, which have so long united the two bodies, have not been weakened during my tenure of office. Survey men are proud of their connexion with this Society, and they share, I know, in the gratification which this new expression of the Society's good will towards us cannot but create in our minds.

If anything could add to the personal pleasure of the award it would be that the medal should be placed in my hands by an old and valued friend like yourself. It is such little touches of human interest which warm and light up formal ceremonies like these. But there is a further source of satisfaction in the fact that while you, Sir, are President of the Society, you are also, at the same time, the worthy and honoured head of that great department of the National Museum which is specially consecrated to the cultivation of our beloved science. The Triple Alliance of the Society, the Museum, and the Survey is a league neither for offence nor for defence, but stands as a symbol of that brotherhood which unites the promoters of science in one common bond, and as a type of that union of the spirit of emulation with the spirit of co-operation to which the advance of Geological Science in this country is so largely due.

Award of the Wollaston Donation Fund.

The President then presented to Mr. W. W. Watts, M.A., F.G.S., late Fellow of Sidney Sussex College, Cambridge, and now of the Geological Survey of England and Wales, the Balance of the Proceeds of the Wollaston Donation Fund, addressing him as follows :—

Mr. Watts,—

In presenting to you the Balance of the Proceeds of the Wollaston Fund the Council of the Geological Society desire to recognize the

value of your work amongst the Igneous Rocks, both in the field and with the microscope.

Your papers 'On the Igneous and Associated Rocks of the Breidden Hills' (1885), 'The Igneous Succession in Shropshire' (1888), and 'On the Geology of the Long Mountain' (1891), give evidence of your careful study of the stratigraphy and palæontology of the older Palæozoic rocks, and of the petrology of the igneous rocks associated with them.

Your observations on the Corndon dolerite showed, for the first time, that a mass of igneous rock presenting a definite laccolite-structure was to be found in this country.

The general results of your work are embodied in the important memoir on 'The Geology of South Shropshire,' by Prof. Lapworth and yourself (published in the Proceedings of the Geologists' Association, 1894).

For several years you have rendered much valuable service as Secretary and Recorder of Section C, at the British Association.

Latterly you have devoted yourself more especially to the study of Igneous Rocks—and the Geological Survey is to be congratulated on having secured your services.

Mr. Watts, in reply, said:—

Mr. President,—

I am deeply sensible of the honour conferred upon me by the Council in awarding me the Wollaston Grant, but I am overwhelmed by the feeling of my own unworthiness when I read the roll of distinguished men, including the President, who have previously received this award. It is a great pleasure to take it from the hands of one who has, throughout my career, shown me unvarying kindness and consideration; and my pleasure is further enhanced by the fact that at the same time my chief, Sir Archibald Geikie, receives the oldest medal granted by the Society. What work I have done has been largely due to the help and encouragement that I have received from Prof. Lapworth, with whom the paper on the Geology of South Shropshire was written during last year. I think it is a subject for congratulation, not only within the ranks of the Geological Survey but outside them, that such candid statement of fact and such free discussion of opinion are, under its present direction, not only permitted but encouraged amongst the officers of that Survey.

Award of the Murchison Medal.

In handing the Murchison Medal (awarded to Prof. Dr. Gustav Lindström, For.Memb.G.S.) to Dr. G. J. Hinde, V.P.G.S., for transmission to the recipient, the President said:—

Dr. Hinde,—

The Council of the Geological Society have unanimously awarded the Murchison Medal to Prof. Gustav Lindström, F.M.G.S., of the State Museum in Stockholm, in recognition of his long and valuable services, extending over 46 years, devoted to the description of the fossil faunas of the Silurian System, in the classical district of Gotland. Thirty years ago Prof. Lindström settled the structure and affinities of that truly remarkable group of the Operculated Corals (1866, 1871, 1883) and the curious Brachiopod genus *Trimerella* (1868); he has dealt with the Silurian Corals of North Russia, Siberia, and North China, and described the Triassic and Jurassic fossils of Spitzbergen. His great work on the Silurian Gasteropoda and Pteropoda of Gotland merits special and honourable mention; as also his paper on the singular Cephalopod *Ascoceras* (1888–90). By his discovery of a fossil air-breathing Scorpion (*Palæophonus*) in the Silurian of Gotland he assisted to carry back land-animals into Silurian times. His Catalogue of Silurian Crustacea and of Swedish Fossils, and his labours to illustrate both the Crinoidea and Trilobita of Sweden (left unpublished by Angelin), must also be mentioned. Nearly all these memoirs have been simultaneously issued in Swedish and English, so that Prof. Lindström's works form really an integral part of our own literature.

These are, after all, but a few out of the many important researches which have occupied Prof. Lindström's long and laborious life. He is already a Foreign Member of our Society,—now the Council desire to add the further recognition of his distinguished services to Geology by sending him this appropriate Medal, with their heartiest good wishes and regards.

Dr. Hinde, in reply, said:—

Mr. President,—

I esteem it a privilege to have been asked by my friend Prof. Lindström to represent him on this occasion. He desires me to express his regret at his inability to be present in person, and he

has forwarded to me a letter conveying his acknowledgments, which reads as follows:—

"Allow me to express my deeply-felt gratitude for the honour which the Council of the Geological Society have bestowed upon me by the award of the Murchison Medal.

"It would not have been possible for me to receive a more appropriate and gratifying mark of approval of my labours in Silurian Palæontology than this, as I may, in truth, say that I owe to Sir Roderick Murchison the first stimulus to my palæontological studies. In 1845, when I was quite a boy, much wondering at the marvellous things I saw enclosed in the limestone-rocks of my native island of Gotland, Sir Roderick, accompanied by M. de Verneuil, visited the island and ranged its strata, along with the other old 'transition rocks' of Sweden, in his newly-founded realm 'Siluria.' This fact acted on me as a fresh revelation, and indicated the path upon which to proceed.

"Later on in life, after having profited by the vast learning of my venerable friend and teacher, Prof. Sven Lovén, I visited London to study your splendid collections, and Sir Roderick was the first to show them to me and to introduce me to the Meetings of your illustrious Society. Thirty-four years are gone by since then, but who could ever forget the words heard within its precincts from such men as Lyell, Horner, Owen, Murchison himself, and other heroes of the science?

"My gratification at receiving the honour of the Murchison Medal is the more enhanced by its coming through your hands, Mr. President, whom I can claim as the oldest living acquaintance that I have in England, and to whom I moreover owe a great debt of gratitude for much kindness shown during a period of more than three decades."

May I be allowed to add, Mr. President, that, though Prof. Lindström's services to Palæontology—of which you have spoken so sympathetically—date back to a period nearly fifty years ago, yet they are by no means concluded, for since the announcement was made of the Council's intention to award this Medal there has appeared a paper by Prof. Lindström in the 'Transactions' of the Royal Swedish Academy of Sciences, containing a description of a new species of fish from strata of Wenlock age in Gotland, which is claimed to be not only the most ancient fish, but the oldest vertebrate fossil yet discovered.

Award of the Murchison Geological Fund.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Mr. Albert Charles Seward, M.A., F.G.S., addressing him in the following words:—

Mr. Seward,—

The Council of the Geological Society have awarded to you the Balance of the Proceeds of the Murchison Geological Fund, in recognition of your work on Fossil Botany, and to aid you in your further researches in this field of investigation. Your early training in Vegetable Biology gives you a great advantage in the study of fossil plants, and your various papers during the past seven years, as well as the Catalogue of Wealden Plants upon which you are now engaged, and of which the first part is published, give promise of still more valuable results in the future, which I trust you may live to verify.

Mr. Seward, in reply, said:—

Mr. President,—

In expressing my heartiest thanks to the Council of the Society for the Award which I have just received at your hands, I can only venture to hope that my future endeavours in the study of fossil plants may, to some extent, make amends for the insufficiency of my present claim to such generous recognition.

In the list of past recipients of the Murchison Award there are included the names of some of the pioneers of Palæontological Science, and it must always be my aim, as it is indeed my duty, to follow their example in the promising and rich field of research in which they so successfully laboured. I should like to add, Sir, that my thanks are due to you for the stimulus which you have given to my work. It was through your initiative that I was enabled to undertake the task of describing our Wealden flora, a work which I hope to complete with as much speed and accuracy as may be.

Award of the Lyell Medal.

In handing the Lyell Medal (awarded to the Rev. J. F. Blake, M.A., F.G.S.) to Prof. J. W. Judd, F.R.S., V.P.G.S., for transmission to the recipient, the President addressed him as follows:—

Prof. Judd,—

The Council have awarded the Lyell Medal to the Rev. J. F. Blake, in recognition of the valuable services which he has rendered to Geology and Palæontology by his zealous and disinterested labours during the past quarter of a century. In that important work on 'The Yorkshire Lias,' by Prof. Ralph Tate, F.G.S., and himself, published in 1876, he gave the first detailed account of the palæontology of the successive stages of the Lias, with records of the stratigraphical characters of each. He furthermore described and figured many of the organic remains, and especially the Cephalopoda, which then, as in later years, attracted his attention.

Continuing for a while to devote himself to the study of the Jurassic rocks, Mr. Blake communicated to this Society papers on the Kimeridge Clay and on the Portland Rocks; and (together with Mr. W. H. Hudleston, F.R.S.) an elaborate memoir on the Corallian Rocks of England.

Mr. Blake's monograph on British Fossil Cephalopoda from the Palæozoic rocks (1882) deserves especial mention.

In later years he has wandered in many fields among the older Palæozoic and Metamorphic rocks—ever and anon seeking relief among less ancient deposits.

In his 'Annals of British Geology,' of which three volumes have appeared (1890–92), Mr. Blake has laboured most industriously to render further service to Geological Science.

Will you convey to Mr. Blake, with this Medal, our most sincere wishes for his health and for the success of his mission to Baroda? In India he will doubtless gather fresh stores of geological knowledge, the acquisition of which has been his happiest pursuit in life.

Prof. Judd, in reply, said:—

Mr. President,—

I cannot but regret that the recipient of this Medal is not able to be with us this afternoon, and to hear the graceful terms in

which you have spoken of his work. Mr. Blake has been called away to India, to discharge important duties there, and I cannot but feel that his exile from home will be rendered more tolerable by this recognition of his past work and by the assurance—which this Award will surely convey to him—that his numerous friends in this country are not unmindful of him. He has asked me to "represent to this Meeting what solid satisfaction the Award gives him," and he requests me to add that "any geological work I have done, or may be doing, has never been done for the sake of honour, but—as Prof. Lodge once said—'if a man feels that he has a call for any line of research, he is bound to obey it, and woe to him if he fails to do so. Necessity is laid upon him!' In the rough and tumble of the work, it is often a matter of doubt whether the call has been rightly obeyed, and whether the work is as good as it should be. As against such discouragement, this Award will always remain a bulwark. It will be a perpetual reminder that my co-workers sympathize with me, and appreciate every effort at its full—or more than its full—value."

Award of the Lyell Geological Fund.

The President then presented one-half of the Balance of the Proceeds of the Lyell Geological Fund to Mr. Percy Fry Kendall, F.G.S., and addressed him as follows:—

Mr. Kendall,—

Some 12 years ago your attention was directed to the study of the fossils of our English Crags, and in 1886, in conjunction with the late Robert Bell, F.G.S., you gave to this Society an excellent account of the fauna of the newly-discovered Pliocene beds of St. Erth in Cornwall. Since then your observations have been concentrated chiefly on Glacial deposits, and in elucidating some of the difficult problems connected with their origin. I would especially call attention to your very full and careful account of the Glacial Geology of the Isle of Man (1894), in which you have shown yourself a most enthusiastic and painstaking geologist. The Council desire your acceptance of this moiety of the Lyell Fund—which may serve to attest their appreciation of your scientific labours.

Mr. Kendall replied in the following words :—

Mr. President,—

The honour which the Council of the Geological Society has conferred upon me was entirely unexpected, as I have not as yet ventured to submit any of the results of my work upon the superficial deposits of our country to the ordeal of criticism in this room.

I have had in my career the good fortune to be brought under the influence of two Fellows of the Geological Society, to whose inspiration and example I owe more than words of mine can express, and by whom I have been directed into fields of enquiry that have yielded me subjects of study of constant and absorbing interest.

The late Mr. Robert G. Bell, whose unobtrusive, and for the most part unpublished, labours are known to but few, gave me a training in Upper Tertiary Palæontology which I have found of priceless value in the study of the more recent deposits. To the late Prof. H. Carvill Lewis, moreover, I owe a deep debt of gratitude for awakening in me, during a too brief intercourse, an interest in the complicated and fascinating problems of Glacial Geology.

The Award of a moiety of the Lyell Fund I gratefully accept as an assurance from my brother geologists that my observations have been of some help in advancing the science, though they have led me to conclusions which are not generally adopted. Thus encouraged I shall return to my pleasant labours animated by a new zeal.

The President then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund (awarded to Mr. Benjamin Harrison, of Ightham) to Prof. T. Rupert Jones, F.R.S., F.G.S., for transmission to the recipient, and addressed him as follows :—

Prof. Rupert Jones,—

The Council of the Geological Society desire to express to Mr. Benjamin Harrison their appreciation of his earnest labours carried on for more than fifteen years in the neighbourhood of Ightham, resulting in the remarkable discoveries of Palæolithic Flint Implements of special character, lying on the surface of the plateau at all levels up to nearly 600 feet above the sea. Some idea of their

abundance may be formed from the fact that Mr. Harrison has collected more than 400, within a radius of 5 miles of Ightham.

Mr. Harrison's discoveries in the Plateau-gravels of Kent have resulted in important communications from Prof. Prestwich to this and other Societies, and I now beg you to convey to Mr. Harrison this Award, as a slight testimony of the interest which the Council have taken in his work and of their desire to aid him therein.

Prof. Rupert Jones, in reply, said:—

Mr. President,—

I shall have very great pleasure in conveying this Award to Mr. Benjamin Harrison, and, with your permission, I will read the following note which I have received from him:—

'It is difficult for me to express my thanks for the honour conferred upon me, and for the kind words of the President.

'At first I carried on my geological investigations almost alone, but was encouraged by Professor Prestwich and Sir John Evans; and my work soon developed into a systematic search for Flint Implements in the Valleys of the Shode, Medway, and Darent, and more recently on the Chalk Plateau.

'Some of the Stone Implements thus found, which were used by an ancient Kentish people, are so rude that it is with diffidence that, by some persons, they have been accepted as the handiwork of Man. But it is an evidence of the great interest which they create that, while the question of their origin has been a subject of doubt in some quarters, the Society has on this occasion and in this manner encouraged further search for these geological relics.

'This chapter in the early history of mankind is yet very fragmentary, but I confidently anticipate the discovery and careful study of further material for its completion by some of the many distinguished observers who have interested themselves in the subject.'

Award of the Bigsby Medal.

In handing the Bigsby Medal to the Hon. T. F. Bayard, Ambassador of the United States, for transmission to Charles D. Walcott, Esq., F.G.S., Director of the United States Geological Survey, the President addressed him as follows:—

Sir,—

It was the desire of the late Dr. J. J. Bigsby, F.R.S., the founder of this Medal, that it should be awarded biennially, 'as an acknowledgment of eminent services in any Department of Geology—irrespective of the receiver's country.'

Moreover, 'the recipient must not be older than 45 years last birthday.' It therefore appeared to the Council of the Geological Society to be peculiarly appropriate to present it to-day to Mr. C. D. Walcott, the Director of the United States Geological Survey, who is now in his 45th year. This is also the fourth occasion upon which this Medal has been transmitted to eminent Geologists in America, where so many of Dr. Bigsby's own researches were carried on.

Few men have attained to a more distinguished position in Geology, or have achieved a larger share of original work in twenty years, than Mr. Walcott. He long held the post of Palæontologist on the U.S. Geological Survey; then that of Chief Geologist; and lastly he has been appointed Director.

As palæontologist, Mr. Walcott laboured most assiduously for many years at the investigation of the structure and organization of the Trilobites, and was the first satisfactorily to show, by means of thin sections, the limbs and branchial appendages of these Palæozoic crustacea. The accuracy of his work has been largely confirmed by the subsequent discoveries of Trilobites showing limbs from the Lower Silurian of Rome, New York.

As a stratigraphical geologist, Mr. Walcott has contributed many papers to science, but his most exhaustive labour has resulted in the production of his great monograph on the fauna of the Lower Cambrian, or '*Olenellus*-zone,' which defines most clearly a remarkable series of rocks, containing the oldest fossil fauna yet discovered, and capable of being paralleled and identified by its fossils nearly all over the world.

These ancient rocks contain no fewer than 59 genera and nearly 150 species of organisms, from sponges, corals, and trilobites to mollusca; and this assemblage of genera appears to be extremely constant over widely-separated areas of the earth's surface.

Do me the favour, Sir, to convey this Medal from the Council of the Geological Society to Mr. Walcott, in token of the admiration with which we regard his work as a geologist, and as expressive of the warm sympathy and attachment existing between English and American men of science to-day.

The Ambassador replied as follows :—

Mr. President,—

There is but a single drawback to my pleasure on this occasion, and that is the absence of my fellow-countryman, Dr. C. D. Walcott, whose merits, and services to Science, you have so generously recited, and by this Medal have so fittingly rewarded.

Dr. Walcott has been awarded this Medal *ex debito justitiæ*—not merely *honoris causa*—and I feel the greatest satisfaction that I should have been deputed by him to receive it in his name and stead, and permitted by your courtesy so to act for him.

The gratification of Dr. Walcott will be sincere, and his feelings may be best expressed by the couplet:—

> 'Praise from such lips 'tis mine with joy to boast—
> They best can give it who deserve it most.'

And the gratification will not be confined to him, but throughout that broad land it will extend among his countrymen, who will be proud and well pleased to see merit recognized, and honour bestowed upon one of that country's deserving sons.

And I must personally acknowledge more than my equal share of the pleasure that I feel in the bestowal of the honour, for I am here as the Envoy of my Country—and especially charged with the maintenance of friendship, goodwill, and confidence between the people of both Nations—so that, when I realize the service performed by such an occurrence as this in swelling the current of good understanding and friendship between the peoples of the two Countries, my sense of obligation to your Society and its Fellows is sensibly strengthened.

For my fellow-countryman I receive this mark of distinction—and in his name, and in the name of his country, and for myself, I return you thanks.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

Henry Woodward, LL.D., F.R.S.

Gentlemen,—

By the death of Chevalier Dr. Josef Szabó, of St. Miklós, Hungary has lost the geologist who has contributed most to our knowledge of the structure of that country and the foremost representative of Magyar science. Szabó was born in 1822; he was educated in metallurgy; his first contribution to science was a memoir on that subject; this he read, at the age of 23, at a sectional meeting of the Hungarian Association of Doctors and Naturalists at Pecs. His paper gained such high approval that he was asked to repeat it before a meeting of the whole Association. After the end of his academy course he settled at Buda-Pest, and began a detailed investigation of the geology of the surrounding country. At intervals in this work he made excursions further afield, and issued memoirs on the geology of Ipolypaszto and Veghles, and various other districts, as well as minor contributions to science. In 1858 the results of his main study were issued in the form of a geological map of the neighbourhood of Buda-Pest. The next year he became a volunteer member of the staff of the k.-k. geologische Reichsanstalt of Vienna, and surveyed the country of Nograd. By his field-work his interest was directed in two different channels—one practical and economical, the other theoretical and abstract. He saw the need for a closer application of geology to agriculture, and was thus led to arrange for surveys, having special reference to agricultural geology, to be undertaken by the Hungarian Geological Institute. He was led by constant work on volcanic rocks in the field to turn his attention to the examination of those rocks in the study. When, therefore, the labours of Zirkel and Vogelsang called more prominent attention to the results that might be obtained by the microscopic investigation of rock-structure, Szabó, though already an old man, at once took up with enthusiasm the task of applying and perfecting these methods of enquiry. Though he was still an enthusiastic collector of fossils, and continued to write occasional palæontological papers, petrography henceforth was his main study. It is probably by his work on this subject that he will be longest known, and it is in this subject that his two principal successes were achieved. He grasped at once the importance of the triclinic felspars in rocks and the difficulty in

the identification of the different species. Hence he began his experiments in order to discover some simpler method of determining these by flame-tests. His results were published, first in 1873, in the 'Verhandlungen der k. k. geologischen Reichsanstalt,' and then in greater detail in Buda-Pest in 1876.

In these works he described the method with which his name has been coupled, and has become familiar in every geological laboratory. His second most important work was that entitled 'Die geologische Beschreibung von der Umgebung von Selmecz (Schemnitz),' issued in 1892. In this he described the series of Kainozoic lavas in the classical district of Schemnitz, ranging from the orthoclase-trachytes of the Lower Oligocene, the andesine-labradorite 'trachytes,' as he called them, of the Aquitanian and the Miocene, to the still more basic anorthite-bytownite 'trachytes' of the Pliocene, and the basalts of the post-Pontian period. He did not, however, confine himself to a mere description of the rocks, for with Szabó lithology was of interest mainly from its bearing on the broader problems of geology. He traced the gradual increase in the basicity of the lavas from the earliest to the latest members of the Schemnitz series; he pointed out the greater fusibility of the magmas compared with the crystalline constituents of each rock, and determined the bearing of these facts on the general problems of vulcanicity. His most original contribution to the subject was, however, in his classification of the rocks; he laid stress on 'habit' as well as on chemical and petrographical characters, and thus proposed an altogether new scheme of the relations of the trachytes and andesites. Whether he will be followed in this may well be doubted, but no one can question the value of the great monograph which was the crowning achievement of his life. But before this had been published Szabó had gained high honour at home and abroad; he was a Knight of the kingdom of Hungary, President of the Geological Society of Buda-Pest, Professor in the University of that city, Correspondent of the Geological Institute of the Austro-Hungarian Empire, and a Foreign Member of this, as well as of numerous other Scientific Societies.

He died on 10th April, 1894, at the age of 72. A posthumous note on the trachytes of the Danubian Hills is the last of a long list of over 150 papers which he contributed to the geology of his fatherland.—[J. W. G.]

In Gustave Honoré Cotteau France has not only lost a well-known judge, but one of her leading palæontologists. He was born

in 1828, and was trained for the law. But he early took a keen interest in the Natural History of the Department of the Yonne, with which he was always associated. At the age of 19 he published his first papers on science; these were a sketch of the geology of the department, and a short paper on the glaciation and erratics of Châtel-Censoir, a locality which he subsequently made famous by the description of its echinoid fauna. He began work as a general geologist and palæontologist, writing papers on Jurassic stratigraphy, on fossil mollusca and fish (on *Ptycholepis* in 1865), on caves (1859), and even on recent mollusca (1854). At the age of 21 he had, however, begun a monograph on the fossil Echinoids of the Department of the Yonne, a work which was not concluded till 27 years later. He soon became especially interested in this group, and after the death of his illustrious friend, E. Desor, was recognized as the foremost of descriptive systematic echinologists. His principal works were his series of monographs on the Echinoidea of the departments of the Yonne (1849–1876), the Aube (1865), and the Sarthe (1855–1869), the last of which was written in conjunction with Jules Triger; on those of Algeria (1876–1885), a work shared by MM. Peron and Gauthier; the two series of memoirs entitled 'Echinides nouveaux ou peu connus' (1858–1893); and, finally, his description of the Echinoidea of the Jurassic, Cretaceous, and Eocene systems in France. The last was issued in the 'Paléontologie Française,' in continuation of the work begun by Alcide d'Orbigny; it occupied six volumes of text, and is illustrated by an atlas of over 1100 plates. But, in addition to these, he wrote over 100 shorter contributions. Most of these dealt with small faunas of Echinoidea, or with species of especial interest from their structure or distribution. Echinoids from all parts of the world were sent to him for description. The most interesting faunas came from Australia, Mexico, Cuba, St. Bartholomew, and Anguilla (1875 and 1877), Syria, India, Belgium, and Spain. The two most remarkable genera that he described were probably *Asterostoma* and *Tetracidaris*, the latter of which is the only post-Palæozoic echinoid known that has more than two rows of plates in each interradius.

Cotteau's work was characterized by most scrupulous care in describing new species; he gave lengthy descriptions of his specimens rather than succinct diagnoses, but these are models of detailed examination and accurate description.

Some of the younger palæontologists were inclined to think that he attached exaggerated value to minute differences and variations, but in the description of specimens from foreign localities this is an

error on the right side, and, whenever Cotteau determined European species in other continents, his conclusions have been implicitly accepted.

M. Cotteau was elected a Foreign Correspondent of this Society in 1874, a Foreign Member in 1891, and a Correspondent of the Academy of Sciences of Paris in 1887. He has bequeathed his fine collection of Echinoids to the Muséum d'Histoire Naturelle in Paris. He was working almost to the end, for copies of five papers published last year were received by the Society shortly after his death, *addressed by himself*, and left ready for the post. He passed away on the 10th August, 1894, in his house in Paris, in the 67th year of his age.—[J. W. G.]

George Huntington Williams was born at Utica, N. Y., in 1856. He graduated from the Utica Free Academy, entered Amherst College in 1874, and took his first degree in 1878. While at college he caught his enthusiasm for geology from his Professor, B. K. Emerson, and spent a year in graduate studies at Amherst. He then went to Berlin, where he perfected his knowledge of German, and to Heidelberg, where he became a devoted pupil of Rosenbusch, and took the Ph.D. degree in 1882. In the following year he became a Fellow in the Johns Hopkins University, where he was appointed Professor of Inorganic Geology in 1885, which position he still held at the time of his death, which took place on July 12th, 1894. Prof. Williams was elected a Foreign Correspondent of the Geological Society in 1892.

Petrography and crystallography were the special departments of geology which he cultivated, and his text-book on crystallography is a lucid exposition of the methods of research in this line. At the time of his death he was at work on a treatise on the 'Microscopic Structure of American Crystalline Rocks.' He was one of the best authorities on these subjects in America, and served as one of the judges of award in the department of Mineralogy at the Columbian Exposition. His untiring devotion last summer at Chicago to the duties thus put upon him may, it is feared, have laid the foundation of the disease which sapped his otherwise vigorous constitution. Prof. Williams was an attractive teacher, and had a peculiarly pleasing manner in both private conversation and public address. The animated and clear descriptions which he gave of even the most technical subjects went far to interest his hearers in any topic that he chose to speak upon. His broad education, attractive

personal qualities, and thorough acquaintance with the facts of his science gave him a prominent place among his fellows, and, although still a young man, he was rapidly rising to honour and fame.

It falls to the lot of but few men who have spent the greater part of their lives in a provincial town to attain to so eminent a position in science and become so widely known and highly esteemed as was the late William Pengelly, of Torquay.

Though seldom present at our scientific meetings in London, he was a prominent figure at the annual gatherings of the British Association, in the direction of the Geological Section of which he took, for many years, a very active part.

Born at East Looe, in Cornwall (January 12th, 1812), William Pengelly was the son of Richard Pengelly and Sarah, his wife (*née* Prout), a cousin of Samuel Prout, the well-known water-colour painter.

When quite a child he was sent to the village-school at Looe, which he attended until he was 12 years of age (1824), when he went to sea with his father, and never had any further instruction at school or college. During the ten or more years, which then followed, of his life as a sailor-lad he suffered many hardships. Once all the crew were shipwrecked and rescued with difficulty, and he was nearly drowned on three separate occasions—once being so long immersed that animation was restored with difficulty.

After the death of his only brother, he abandoned his seafaring life, at the earnest desire of his mother, and set himself the still more arduous task of self-education. How he laboured and persevered, and gradually succeeded, is seen by the sequel. Under the influence of one of his mother's relatives, William Pengelly went to Torquay, and, in 1836, started a school upon the Pestalozzian system, the principle of which was teaching by demonstration; the use of the blackboard and chalk; and greatest of all moral lessons—that "the relation between teacher and scholar should be that of love." In 1837 he established the Torquay Mechanics' Institute, in the classes and lectures of which he was himself most active.

His system of instruction was so highly appreciated, and he had so many private pupils, that after ten years (1846) he relinquished his school and became a private tutor in Mathematics and Natural Science. But he did not forget his early struggle for education, and established a night-school for men and boys, whom he taught gratuitously for many years. As a tutor he must have been very successful,

having, in his younger days, numbered amongst his pupils the nephews of the late Czar, Prince Nicholas, Prince Sergius, and Prince Eugene; the Queen of Württemberg, the Princess Mary of the Netherlands, and the Baroness Burdett-Coutts.

There was a certain charm of manner about William Pengelly which attracted people to him, and even his occasional brusqueness of style and a touch of the pedagogue in his bearing were overlooked in the change to merry roguishness which commonly characterized him thirty years ago, 'when we were first acquaint'; indeed, so pronounced was this peculiarity that, at our meetings at the British Association, he was commonly known amongst his friends in Section C by the sobriquet of '*Pun*-gelly,' in allusion to his inveterate habit of punning.

On October 11th, 1844, Mr. Pengelly, Mr. Vivian, and 15 other gentlemen met at the house of Dr. Battersby for the purpose of establishing the Torquay Natural History Society, and, had Mr. Pengelly lived seven months longer than he did, he would have been witness of its jubilee. He was honorary secretary for nearly forty years, and the last-surviving founder. Indeed, during the past fifty years he has been the active spirit to whom the Society owes, not only its existence, but its continued success and the high position which it holds in Torquay at the present day.

In 1850 Pengelly was elected a Fellow of the Geological Society, of which he remained a member till his death, a period of forty-four years.

One of Pengelly's first recorded papers was 'On the Ichthyolites of East Cornwall'[1] (1849–50). These interesting remains were first identified as Fishes by C. W. Peach in 1843; after eight years they were referred to Sponges under the name of *Steganodictyum cornubicum*, in 1851, by M'Coy[2]; then to the Cephalopoda by Ferd. Roemer (as *Archæoteuthis dunensis*) in 1855; and back again to the Fishes as *Scaphaspis cornubicus*[3] by Huxley in 1868. Pengelly mentions, in one of his papers, that he had no fewer than 300 fragments of these fossil fishes from the Devonian of Cornwall and Devon in his own cabinet.[4] He read a paper on 'Beekites' before the British Association in 1856, and on the 'Ossiferous Caves and

[1] Trans. Roy. Geol. Soc. Cornwall, vol. vii. pp. 106–108 & 115–120.

[2] Ann. & Mag. Nat. Hist. ser. 2, vol. viii. (1851) p. 482.

[3] Huxley, Geol. Mag. 1868, p. 248, H. Woodward & E. R. Lankester, p. 247 & p. 437, and Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 546.

[4] Trans. Devon. Assoc. vol. ii. (1868) p. 440, and Geol. Mag. 1869, p. 77.

Fissures of Devonshire' before the Royal Institution of Cornwall (1858–59, vol. iii. pp. 149–151).

In 1862 he communicated a paper to the Royal Society 'On the Lignites and Clays of Bovey Tracey.'[1] This was afterwards supplemented by Dr. Oswald Heer's account of 'The Fossil Flora of Bovey Tracey,' and was issued as a separate volume, dedicated to Miss Burdett-Coutts (who undertook the expense of the publication).

Pengelly's first systematic Cave-exploration, that of Brixham Cave, near Torquay, was undertaken in 1858, under the auspices of the Royal and Geological Societies, aided by a committee consisting of Sir A. Ramsay, Prof. Prestwich, Sir C. Lyell, Sir R. Owen, Mr. Beckles, the Rev. R. Everest, Mr. Godwin-Austen, and Dr. Hugh Falconer. But the actual exploration was carried out by Pengelly himself, who undertook the entire superintendence.

In 1862 he initiated the establishment of the Devonshire Association for the Advancement of Science, Literature, and Art, of which he was the President for 1867–68.

In recognition of his past scientific work he was elected a Fellow of the Royal Society in 1863.

Ever eager to foster a love for science among the people and to encourage those studies which had for their object the advancement of knowledge, Pengelly was especially active as a lecturer; he had the happy faculty of making himself easily understood by persons unacquainted with science. Twenty years ago he travelled through the country as one of the most acceptable scientific lecturers of the day, and his efforts locally were equally successful.

The exploration of Kent's Cavern commenced in the year 1864; a committee, consisting of Sir Charles Lyell, Prof. Phillips, Sir John Lubbock, Sir John Evans, Mr. Edward Vivian, and Mr. William Pengelly, was formed at the British Association, Bath, and, year by year from 1865, Pengelly, acting as Secretary, brought up to the Association his annual Report of the work carried on in Kent's Cavern under his constant care and supervision.

"This famous cave, better known as 'Kent's Hole,' is situated in a small limestone-hill about a mile eastward from Torquay harbour; it has been known from time immemorial, but never attracted scientific attention until 1824; it was partially explored by the Rev. J. McEnery from 1825 to 1829; by Mr. Godwin-Austen prior to 1840; and by the Torquay Natural History Society in 1846. All

[1] Phil. Trans. Roy. Soc. vol. clii. (1862) p. 1019.

the explorers were agreed as to the finding of flint 'implements,' of undoubted human origin, mixed with remains of extinct animals, in ordinary cave-earth, beneath the floor of stalagmite."

The exploration initiated in 1864 was carried on until 1880—or for a period of nearly sixteen years. During the greater part of this time, so enthusiastic and persevering was Pengelly that (according to his own statement) he had never, while at home, failed on a single week-day to visit the cavern, wherein he usually laboured five hours a day. Between 1866 and 1880 inclusive the British Association voted the sum of £1850 for the Kent's Hole explorations, exclusive of sums contributed by various scientific friends.

Few men in their prime could have led a more active and energetic life than did William Pengelly. But the carrying on of the affairs of three or more local scientific societies, the frequent lecturing in Torquay and other places, the giving private lessons to numerous pupils, even the additional burden of the exploration of Kent's Cavern, all these did not preclude him from writing scientific papers for various societies.

No fewer than 112 papers are placed to his credit in the Royal Society's Catalogue of Scientific Papers, embracing widely different subjects, those on Cave-exploration and Geology being, however, predominant.

On one occasion Mr. Pengelly observed, 'The pleasure of the work is the payment'; but nevertheless his friends were not unmindful of one who had done so much for the advancement of science and education in their midst. Commencing with the presentation of a valuable telescope for his lectures on Astronomy in December 1850; a series of the 'Encyclopædia Britannica' in 1857; a purse in May 1858; upwards of 600 guineas and an address in March 1874; his portrait, painted by Mr. A. S. Cope, in 1881; and an illuminated address in 1890, a succession of testimonials bore witness to their esteem and appreciation of his labours.

This Society awarded him the Proceeds of the Lyell Fund in February 1877, and the Lyell Medal and £21 in February 1886.

Pengelly was twice married, but all his children by the first marriage died; the last son, Alfred Pengelly, being killed in India whilst out hunting big game. He leaves a widow and two daughters; both of the latter share their father's scientific tastes.

But few men write their own epitaphs; here, however, is the epitaph written by William Pengelly for himself at the British Association, Exeter, 1869:—

"Here rests his head on balls of *album græcum*,
A youth who loved Cave-earth and stalagmite;
If fossil bones they held, he'd keenly seek 'em!
Exhume and name them with supreme delight.

His hammer, chisels, compass, lie beside him;
His friends have o'er him piled this heap of stones:
Alas! alas! poor fellow! woe betide him,
If in the other world there are no bones!"

He died at his residence, 'Lamorna,' Torquay, March 17th, 1894.

William Topley was born at Greenwich on March 13th, 1841 he received his early education at local schools, but, from 1858 to 1861, he enjoyed the valuable scientific and practical training of the Royal School of Mines.

In 1862 he was appointed an Assistant Geologist on the Geological Survey. He commenced his field-work under the guidance of Dr. (now Professor) Le Neve Foster, who was engaged in the Survey of the Wealden area. There he was initiated into the methods of geological mapping, and gained a detailed knowledge of the Cretaceous and Neocomian formations; his interest was also aroused in questions of Physical Geology, to which, for many years, he gave particular attention.

In conjunction with his colleague, Dr. Foster, he made a study of the superficial deposits over a large part of the Wealden area, and more especially of the gravels of the Medway Valley; and together they elaborated in 1865 the well-known paper in which they brought their knowledge to bear on the vexed subject of the Denudation of the Weald.[1] In this essay they gave numerous facts and new arguments to prove, what had in general terms been taught by Ramsay, that the main features of the ground were sculptured by the agency of rain and rivers.

On the completion of the Geological Survey of the Wealden area, the preparation of the descriptive memoir devolved upon William Topley. Other colleagues, Mr. F. Drew, Mr. C. Gould, and Dr. Foster, who had mapped large portions of the region, had resigned their official positions; but Topley had had numerous opportunities of becoming generally acquainted with the entire district. How carefully his memoir was written is known to every geologist. The book, which was published in 1875, at once became the standard work of

[1] See Quart. Journ. Geol. Soc. vol. xxi. (1865) pp. 443–474.

reference; for, apart from its original information, it gave evidence, as did all his writings, of a thorough study of the publications of other observers, and a full acknowledgment of all that they had done.

Meanwhile Topley had been instructed to proceed to the Coal-field of Northumberland and Durham, and much of his literary labour connected with the memoir had to be performed in that northern region in the winter-time, or at other seasons when field-work was impracticable. In 1868, after six years' service, he had been advanced to the rank of Geologist on the Geological Survey.

When, in 1872, the Committee of the Sub-Wealden Exploration commenced their active operations near Battle, Topley was, of course, specially interested. He was one of the first to be consulted, and, later on, he was expressly sent by the Geological Survey to the locality to examine and report upon the cores brought up by the boring-apparatus. He was thereby enabled to record, in his memoir on the Geology of the Weald, particulars of the strata and their fossils to a depth of over 1000 feet. The classification of the strata given in that work was subsequently modified, and Topley from time to time contributed many reports and other articles on the subject.

A considerable portion of Topley's sojourn in the north was spent at Rothbury, near Morpeth, and at Alnwick, where his studies were directed mainly to the Carboniferous rocks and to the Glacial Drifts. The nature of that great sheet of basalt known as the Whin Sill engaged his attention and that of his friend and former colleague, Prof. Lebour,[1] and the result of their observations was to prove its intrusive character.

The subject of Denudation never ceased to interest Topley, and when, during the early sixties, many warm discussions took place concerning the origin of escarpments and other features, he joined in the fray on behalf of subaërial agents. In confirmation of views that had been expressed with regard to other regions, he pointed out how in East Yorkshire anticlinals, by their fissured summits, had been readily acted upon by inland agents of erosion, whereas, in certain cases, synclinals had better withstood the assaults of rain and rivers.

In 1880 William Topley was called upon to abandon his field-work in Northumberland in order to superintend the publication of Maps and Memoirs at the Geological Survey Office in Jermyn Street.

[1] Brit. Assoc. Rep. Bradford, 1873 (Sections), p. 92; Quart. Journ. Geol. Soc. vol. xxxiii. (1877) pp. 406–422.

This post, which for many reasons was congenial to him, he continued to occupy; and, on the retirement of Mr. Edward Best in 1893, Topley was entrusted with the entire charge of the office. Throughout this period in London the multifarious duties of the department gave but little opportunity for continuous scientific work: ever busy, he was seldom able to do more than the routine work of the office, but his wide knowledge and experience were always at the service of his colleagues and of others who frequently sought advice and information.

Eager at all times to promote the progress of Geology, Topley took a leading part in the work of that most useful compendium of geological literature, the 'Geological Record'; and here his extensive acquaintance with bibliography was of great service. Finally, in 1887, he undertook the post of Editor, at a time when the 'Record' was in somewhat troubled waters, owing to delays in publication. These had arisen, despite every effort made by the untiring and disinterested exertions of the original Editor, Mr. Whitaker. Two volumes, dealing with the literature of 1880–84, were brought out in 1888 and 1889; but, even with the effective help rendered by Mr. C. D. Sherborn, the 'Geological Record' had ultimately to be abandoned.

Topley joined the British Association at the Meeting held in Brighton in 1872, and was at once nominated one of the Secretaries of Section C (Geology). From 1872 to 1888 he served this office during no less than fifteen meetings. He was for several years Secretary of a committee appointed by the Association to report upon the Coast Erosion of England and Wales. He was also for many years a member of the Council of the Geological Society, and President and Vice-President of the Geologists' Association. During his Presidency Mr. Topley led the Association to the Ardennes, to Northumberland, to the Wealden area, and to many other localities in and around London.

When the International Geological Congress arranged for a meeting in London in 1888, Topley (who had attended previous gatherings) was chosen as one of the Secretaries, and then, not only during the meeting, but for a long while before and afterwards, his energies were severely taxed with the many duties which he had to perform.

In 1885 he had prepared an elaborate Report on the National Geological Surveys of Europe; and he was much interested in the question of an international scheme of colouring for geological

maps. He had, in 1881, been appointed to superintend the publication of the British section of the Geological Map of Europe, promised by the International Geological Congress; and in 1888 (conjointly with Mr. J. G. Goodchild) he prepared the excellent little Geological Map of Europe which accompanies the second volume of Prof. Prestwich's 'Geology.'

Thus were his services in constant demand. At one time Agricultural Geology occupied a large share of his attention, and he had gathered together much material bearing on the subject, with the view of publishing a work on Soils in their relation to Geology. Several essays dealing with these matters were printed, and perhaps the most important outcome of his studies in the South-east of England was his paper dealing with the connexion between the parish-boundaries and the great physical features which are dependent on the geological structure. This subject was first brought before the Brighton meeting of the British Association in 1872, and it there attracted considerable attention. The author showed how the ancient divisions of the land were made according to the water-supply, the soil, and situation; portions of down-land being taken to pasture sheep, the productive tracts for agriculture, and portions of forest-land, whether wood or open glade, for swine and as pasture for cattle.

In later years Applied Geology occupied the greater part of Mr. Topley's leisure hours. He had given much attention to the mode of occurrence of Phosphates; he wrote a report on the geological distribution of Gold and Silver; discussed the schemes for the construction of a Channel Tunnel; and wrote concerning the discovery of Coal in Kent.

The subject of Water-supply, however, more than any other engaged his mind, and it was one on which he was recognized as a leading authority. The needs of Hastings, Tunbridge Wells, Croydon, Birmingham, as well as of London, and many other centres, large and small, were investigated and reported on by him; and during the sittings of the late Royal Commission on Metropolitan Water-supply he gave most important evidence, besides officially doing much work for the Commission in the preparation of maps and sections for the Report.

Sanitary Science was another branch of the subject to which he had applied his knowledge. He assisted Sir George Buchanan, in 1867, in a Report on the Distribution of Phthisis as affected by Dampness of Soil; and in 1890 he was appointed chairman of

Section III. of the Sanitary Institute, at the Congress held at Brighton. He then delivered an address on Geology in its relation to Hygiene, as illustrated by the Geology of Sussex.

William Topley's published Memoirs and papers amount to eighty-two in number; his Survey Maps to twenty-one sheets, with three vertical and five horizontal sections, illustrating the Northumberland Coal-field and the Wealden area.

His knowledge, however, was by no means restricted to matters of professional concern. Prof. Le Neve Foster states that in his early days in the Weald his late colleague was fond of Botany, and the two friends collected many specimens for determination at their field-quarters.

Since 1875 Topley had been Examiner in Geology to the Durham University at the Newcastle College of Science; he also succeeded the late Mr. Bristow as Examiner in Geology to the Science and Art Department. He was elected a Fellow of the Geological Society in 1862; an Associate of the Institute of Civil Engineers in 1874; and a Fellow of the Royal Society in 1888.

Full of energy until within about three weeks of his death, he had attended the Zürich meeting of the International Geological Congress. There, as an acknowledgment of his services and a testimony to his wide acquaintance with the subject, the chairmanship of the Committee on Bibliography was offered to him; but this he declined on the ground of insufficient acquaintance with spoken French. Leaving Switzerland, he subsequently paid a short visit to Algiers, when serious illness overtook him. He had barely time to reach his home at Croydon, ere he was prostrated, and he finally succumbed to an attack of gastritis on September 30th, 1894.

The record of his life is one of constant and unremitting labour. Yet he was ever cheery, and what was perhaps most noteworthy, however much he might be occupied, he was always willing, and that without any trace of impatience, to be interrupted.

It is sad to feel that he has left unaccomplished several tasks which he had planned, and which he was peculiarly well fitted to perform; but, nevertheless, he leaves behind him a substantial record of good work done. It is far sadder to think of the loss of a most kindly, amiable nature—of a true friend, whose readiness in helping others too often stood in the way of the fulfilment of his own desires.—[H. B. W.]

The Rev. Edward Hale was born at Hambledon, in Hampshire,

on April 9th, 1828. He was educated first at St. Paul's School, Portsmouth, from which place, at the early age of 14, he went alone to Mannheim, in the Duchy of Baden. He afterwards matriculated at Emanuel College, Cambridge, where he took his degree in 1850, immediately after which he came to Eton, first as Assistant Mathematical Master to the late Rev. S. Hawtrey. In 1855, when Mathematics became an integral part of the school-teaching (which they had not been previously), he was duly appointed one of the Assistant Mathematical Masters of the School, which office he continued to hold till the year 1873, when Physical Science having been, by order of the Governing Body of Eton, constituted one of the subjects to be taught in the school, Mr. Hale, who had made that subject his especial study, was appointed to be one of its teachers, and he continued to teach it till the day of his death.

At the time of Mr. Hale's first appointment there were very few of the Eton Masters who had not previously been Eton boys themselves. Mr. Hale, as we have seen, had not been educated at Eton, but his kindly nature and hearty goodfellowship soon overcame such a disadvantage, if, indeed, it could be called one, in the minds of his colleagues and pupils.

Edward Hale was ordained at Cuddesdon in 1851, and took Priest's orders in 1853, the then Vicar of Windsor conferring upon him the title necessary for ordination, on account of parish-work done by him as Assistant-Curate in the poorer parts of Windsor. He was elected a Fellow of the Geological Society in 1873. He married in 1855, and leaves a family of three sons and four daughters to lament his loss. He died on July 25th, 1894, at his residence, Jordley's Place, Eton, in his 67th year.

No Eton master was better known, and none was better liked. From the first moment that he entered the school he never had an enemy among his colleagues or his pupils. He was one of those men whose very presence and manner inspire confidence and engage friendship. Of the many who as boys lived in his house, and were subject to his rule, there was not one who did not regard him with affection as well as respect. They liked him the better, because they knew that, with all his invariable kindness of heart, he would insist on being obeyed. Bluff and genial in appearance, his manner had a rare and magnetic frankness and *bonhomie* that at once put you at your ease. All young children liked him, and what greater testimony than this can there be to a man's lovable nature?

Henry Bean Mackeson, of Hythe, Kent, was elected a Fellow in 1844, and had consequently been connected with the Society as a non-resident country-Member for fifty years. He died in February, 1894, in his eighty-third year. Mr. Mackeson was well-known as an archæologist and geologist, and was the discoverer of the remains of a large Dinosaur in the Lower Greensand from the vicinity of Hythe, noticed by Fitton in the 'Proceedings of the Geological Society,' June 10th, 1840 (vol. iii. p. 325), and described by Owen under the genus *Polyptychodon*, June 16th, 1841 (*op. cit.* pp. 449–452) [see also Owen, Foss. Rept. Cretaceous Formation, 1851, pp. 47–55, pls. xii. & xiii., Mon. Pal. Soc. 1851–64]; later on re-described by Owen as a Dinosaur under the genus *Dinodocus Mackesoni* (Owen, Hist. Brit. Foss. Reptilia, 1884, vol. ii. p. ix).

Joseph Bickerton Morgan was born in 1859. He was always an earnest student of nature, and took a deep interest in the geology of Wales. He paid special attention to the rocks of the Upper Ordovician and Silurian formations of Powysland and the Welsh border, from which he had obtained a large series of fossils in beds above and below the boundary-line of these formations. He was elected a Fellow of this Society in 1889.

By the advice of Prof. Lapworth he began carefully to map these strata, and succeeded in defining the lower limit of the Silurians with considerable exactitude. He communicated his conclusions on the subject to the British Association at Leeds, 1890. In 1892, having obtained a free scholarship at the Royal College of Science, he came to London, and, after a year's study, succeeded in obtaining the Murchison Medal and gift of books.

In the summer of 1893 his health failed, and he was compelled to abandon work and winter at Ventnor, where he rallied for a time, but finally succumbed on the 8th March, 1894, in his 35th year. He did excellent work in assisting to arrange the Powysland Museum at Welshpool, to the fossils of which he largely added from his own collections.

Lord Swansea, better known as Sir Henry Hussey Vivian, Bart., formerly M.P. for the Swansea district, was the eldest son of the late John Henry Vivian, Esq. Born at Singleton in 1821, he was educated at Eton and at Trinity College, Cambridge; was three times married; was Deputy Lieutenant of Glamorganshire, and formerly Colonel of the 4th Glamorgan Rifles. He was elected a

Fellow of the Geological Society in 1850, and died at his seat, 'Park Wern,' Swansea, November 29th, 1894. He sat in the House of Commons as member for Truro, 1852–57; for Glamorganshire, 1857–85; and for the Swansea district from 1885–93, when he was raised to the peerage.

The only work of which he was the author is entitled 'Notes on a Tour in America.'

James Adey Birds was descended from an old Derbyshire family, the Birds of Locko, Stanton Hall, and Bakewell, Derbyshire. He was the son of the Rev. W. T. Birds, and was born November 9th, 1831, at Preston Rectory, Salop. He was educated at Rugby, and graduated at Christ Church, Oxford. He took a deep interest in geology, was a careful observer of geological facts, and communicated several papers to the Geological Magazine between 1866 and 1881, notably on 'A bed of Chalk-flints near Spa, Belgium' (1866), on the 'Post-Pliocene formations of the Isle of Man (1875), and on the 'Geology of the Channel Islands' (1878), etc.

Mr. Birds was elected a Fellow of the Geological Society in 1878. He was a good classical scholar and linguist, and prepared an English rendering of Goethe's 'Faust' (published by Longmans in two volumes in 1880).

He formed an excellent geological collection, which he bequeathed to the borough of Derby, the chief town of the county where his ancestors had so long resided. He died at West Bournemouth, on December 15th, 1894, in his 63rd year.

The year which has just ended has given us a special subject for congratulation. It has witnessed the issue of the 200th Number and the completion of the 50th Volume of the Quarterly Journal of the Society.

The Council have resolved to celebrate the Jubilee of this important publication—so rich in papers on geological, petrological, and palæontological subjects—by the issue of that most valuable and useful of all accessories to a long series of volumes—an Index for Fifty years.

It is pleasant to notice the steady onward tendency in our Journal for the last year, and to mark its increase, by 158 pages, over its predecessor, together with 16 more plates, and still as many illustrations in the text as appeared in the volume for 1893.

For the admirable manner in which the Journal is edited our thanks are due to our Assistant-Secretary, Mr. L. Belinfante, who is untiring in his efforts to keep the Society's quarterly publication up to the highest standard of excellence.

It follows then as a matter of course that, if our Journal is large and the papers excellent, our evening meetings have been successful and the communications read have been of general interest to our Fellows.

To render our Meetings attractive to Fellows and Visitors, to make our Library as perfect as possible for the Geological student, and our Journal the best of its kind among scientific periodicals,—these are the objects which commend themselves as worthy to be upheld in the best interests of our Society.

Your Council have had before them the question of the publication of a 'Geological Record,' and, after taking the best evidence upon the subject that they could gather, they have come to the conclusion that such an undertaking could not be entered upon either with the present limited Official Staff of the Society or the present annual subscription contributed by its Fellows.

An effort is being made, however, to render still more useful the very valuable list, prepared by Mr. W. R. Jones, of books and papers added yearly to the Society's Library, and to make it the nucleus of a 'Geological Record' so far as its extent allows.

We aim, if possible, at making our Library a complete one as to Geology, Petrology, and Palæontology in the immediate future, and the more nearly we succeed the more nearly will our Record of its contents approximate to a complete Record of our science.

But what we are able to accomplish must largely depend on the prosperity of the Society: in other words, upon the annual income which we derive from our Fellows' contributions, and the proportion which we may justly expend on our Journal and our Library. In reference to the subject of Income, I may venture to express the opinion that our 'Annual Subscribers' are the greatest benefactors to our Society—if only their interest in our science be kept alive, and that I take it to be the main object of the Governing Body of this Society to foster and promote by all possible means.

As an illustration, I will cite the case of one venerable Fellow whose annual contributions have so far amounted to £160—so that he has paid what would have been his 'Composition-fee' of £31 10*s.* about five times over. May all our Annual Subscribers live to imitate his good example!

When our Society first entered upon its mission, in 1807, but few Museums existed anywhere, and Museums of Geology were practically unknown. This Society must for very many years have occupied a unique position as a centre for the diffusion of the knowledge of Geology and as a place wherein to test the new views of Mr. William Smith, the geological land-surveyor, that strata could be identified by organized fossils.

Now all is changed: the British Museum is no longer merely a receptacle for curiosities, but is one of the finest and most famous collections in the world. I said one of the finest, but I need hardly mention the fact here that the Old Museum has undergone subdivision, and its Natural History Section, now separated from the original Institution, almost rivals it in extent, so that, like the 'Heavenly Twins,' they cast a double radiance from Bloomsbury and Cromwell Road.

Then, again, there is the Museum of Practical Geology in Jermyn Street, which possesses an unrivalled collection of British Fossils and would be far more widely known and visited than it is, but for the fact that the architect put its front door in Jermyn Street instead of in Piccadilly, the result being that benighted visitors often fail to find their way in to this very interesting Museum.

In 1874 we moved our geological collections, so rich in figured type-specimens, with our other *lares* and *penates*, from Somerset House to Burlington House. We have preserved them in some order, and have even spent some money upon them; but we need a Curator whose time should be entirely devoted to the task of cleaning, arranging, labelling, and conserving these historical specimens. If we cannot afford to do this very obvious duty by the records of the work of past geologists, of which we are the custodians and our Museum the receptacle, it is obvious that we should, at no distant day, decide to place them in some public Museum, such as the British Museum of Natural History or the Museum of Practical Geology, where they would be duly cared for at the national expense.

As a corollary of the foregoing subject of the Society's Museum comes the question of the Society's Library. We find that just in proportion as the need for the Museum has decreased, the demands upon the Library have increased. Whilst the Library has always required the entire services of an Assistant-Librarian, and has laid claim upon a share of the Clerk's time and upon that even of the Assistant-Secretary also, the Museum only enjoyed the services of

a Museum-Assistant up to 1868 (27 years ago), since which time it has had the benefit of an occasional brief revivification by some enthusiastic Fellow, such as Mr. Sherborn, or some other friend of fossils.

The explanation is obvious. Other Museums exist which are more easily accessible to the Geologist, and which are in charge of a Curator. Books, too, with excellent figures of fossils, have multiplied and increased enormously of late years, and are more accessible even than Museums.

The vast growth of scientific Literature, especially bearing upon Geology, Petrology, and Palæontology, not only in this country but abroad, necessitates the continual enlargement of our Library-space. Moreover the needs of Fellows, causing them to make more and more use of the Library for study, point inevitably in the direction of the requirements of our Society, namely, the possession of a Geological and General Reference Library of the first class, which by its steady growth will eventually call for the transfer of the Museum to another home and the utilization of the space now filled with cabinets of fossils by shelves of books.

Amongst the various matters which have engaged the attention of the Council during the past year has been the question as to what Composition-fee should be paid by Fellows desirous of commuting their annual subscription of £2 2*s*., and the further question as to the amount required to be invested in order to safeguard the interests of those who are already Compounders.

With respect to the amount of the Composition-fee, the Council, after careful consideration, and taking the advice of some of our Fellows who are experienced in financial matters, arrived at the conclusion that the fee of £31 10*s*., fixed in 1877, was insufficient to yield an annual equivalent of £2 2*s*., and therefore they recommended that the fee be raised to £35, to take effect from the 1st November, 1894, for all Fellows who enter the Society after that date and desire to compound; and this recommendation was subsequently adopted by a Special General Meeting. For the 16 years previous to 1877 the 'Composition-fee' was only £21, a sum hardly more than half the actuarial value of £2 2*s*. per annum, and during this interval there was (as might be expected) a large accession to the numbers of the Compounders, to the consequent disadvantage of the finances of the Society. Since 1877 the number of Compounders has remained practically without alteration, for the average number of new Compounders each year has been

balanced by the same average number of deaths, and thus the total number has remained about 305.

It was hinted in the Report of the Council for 1893 that, in view of the investments of the Society having reached the sum of £10,729, the time had arrived to ascertain whether the interests of the Compounders were sufficiently secured, and on this question the Council decided that the present investments were amply sufficient to cover all liabilities in connexion with the present body of Compounders, including those who were admitted on such generous terms in the past, and, consequently, that for the interests of the Compounders, it was not needful, at present, to add further to the invested capital of the Society.

When the Composition-fee was below the actuarial value of the annual subscriptions which it commuted, no money was invested; but during the ten years ending December 31st, 1893, over £2900 has been added to the invested funds of the Society, and these funds now are not only sufficient to guarantee the liabilities for the Compounders, but would be probably sufficient, should it be deemed desirable, to employ a certain amount for laying-in the electric light into the rooms of the Society, in addition to the sum already appropriated by anticipation to the Index for the Fifty Volumes of the Quarterly Journal now being prepared.

That the present financial position of the Society is a sound one is largely due to our retiring Treasurer, the Rev. Prof. Wiltshire, who has carefully husbanded our Income during the thirteen years of his Treasurership, from 1882 to 1895, and for that care of our resources we owe him our hearty thanks. In our new Treasurer, Dr. Blanford, we are not electing a stranger, but one who has served the offices of President and Secretary, and has been on the Council for some years. He is therefore well acquainted with the affairs of the Society, and will, I feel sure, safeguard its finances and at the same time aid in the advancement of its best interests.

Permit me to detain you for a moment to refer to a subject which has of late years largely affected all grades of society and vibrated through all centres of intellectual life in this country—I allude to the change of feeling which has taken place in relation to the question of the 'Higher Education of Women'—[not to that of the 'new cult' miscalled the 'Emancipation of Women,'—which none of us here, I imagine, would care to discuss].

In 1860–61 (about 35 years ago) the President, Mr. Leonard Horner, with the concurrence of Sir Charles Lyell, Sir Roderick

Murchison, and other Members of Council, decided to arrange for the admittance of ladies to the evening Meetings of the Society. It was considered that the Apartments of the Society in Somerset House were inadequate for such a purpose, and leave was obtained to use the Meeting-room of the Royal Society, Burlington House, for the experiment. Accordingly, on the nights of the Meetings, Mr. H. M. Jenkins (the then Assistant-Secretary), Mr. Roberts, the Clerk, with two Assistants and Charlton carrying the books, diagrams, papers, and ballot-boxes in two four-wheeled cabs, repaired to Old Burlington House to hold the Ordinary Evening Meeting. I believe that the Misses Horner attended some of these specially-arranged gatherings, but evidently the attempt was made 25 years too soon, and it was accordingly abandoned as a failure.

The British and the Geologists' Associations admit ladies as Members, and to their Meetings and Excursions.

The Royal Geographical Society and the Anthropological Society admit ladies; ladies have also been present at the reading of papers at the Royal Society and the Society of Antiquaries. The Zoological Society, whilst admitting ladies to Fellowship, illogically excludes them from its Meetings.

I venture to suggest that this Society might once again (after the lapse of 35 years) test experimentally the admission of ladies to attend the evening meetings of the Society, and even, in special cases of original workers, to the use of the Library also.

We have, upon several occasions, received, read, and published scientific papers from lady-geologists, and as lately as 1893 an award was made from the Lyell Fund to Miss Catherine Raisin, B.Sc., 'for her excellent work in Geology both in the field and with the microscope.'

With the many brilliant examples before us of women who have achieved distinction at our Universities and in the various branches of Science and Art, and seeing that Geology has already become popular with ladies of education, by their admission to the meetings and excursions of the British and the Geologists' Associations, we may well, I think, consider whether we have an exclusive right to shut our doors against the advancing tide of public opinion, and whether we should not rather contribute to the higher education of Women by admitting those who desire the privilege, to be present at the reading of papers before this Society.

And now—if your patience be not already exhausted by my too-lengthy preamble—I will beg your indulgence whilst I endeavour to briefly treat of

Some Points in the Life-history of the Crustacea in Early Palæozoic Times.

Of the various groups of the Invertebrata whose ancestry extends into Palæozoic times, none possess a greater interest for the geologist than the Crustacea, whose existence is proved as far back as the Lower Cambrian rocks; while their near allies, the Arachnida, have been met with in strata as old as the Silurian.

My earliest papers on the Eurypterida appeared in 1863 and 1864, and an account of *Stylonurus* and *Hemiaspis* was communicated to this Society in 1865, just 30 years ago. In that year (1865) I had the pleasure, with my friend and fellow-worker, the late J. W. Salter, F.G.S., of publishing a 'Chart of Fossil Crustacea,'[1] in which an attempt was made to show the evolution in time of the various forms belonging to this class, graphically depicted on an engraved folding-sheet, with explanatory text. We pointed out that the main development of the crustacea in Palæozoic times consisted of the great groups of the Trilobita, the Eurypterida, the Xiphosura, the Phyllopoda, and the Ostracoda.

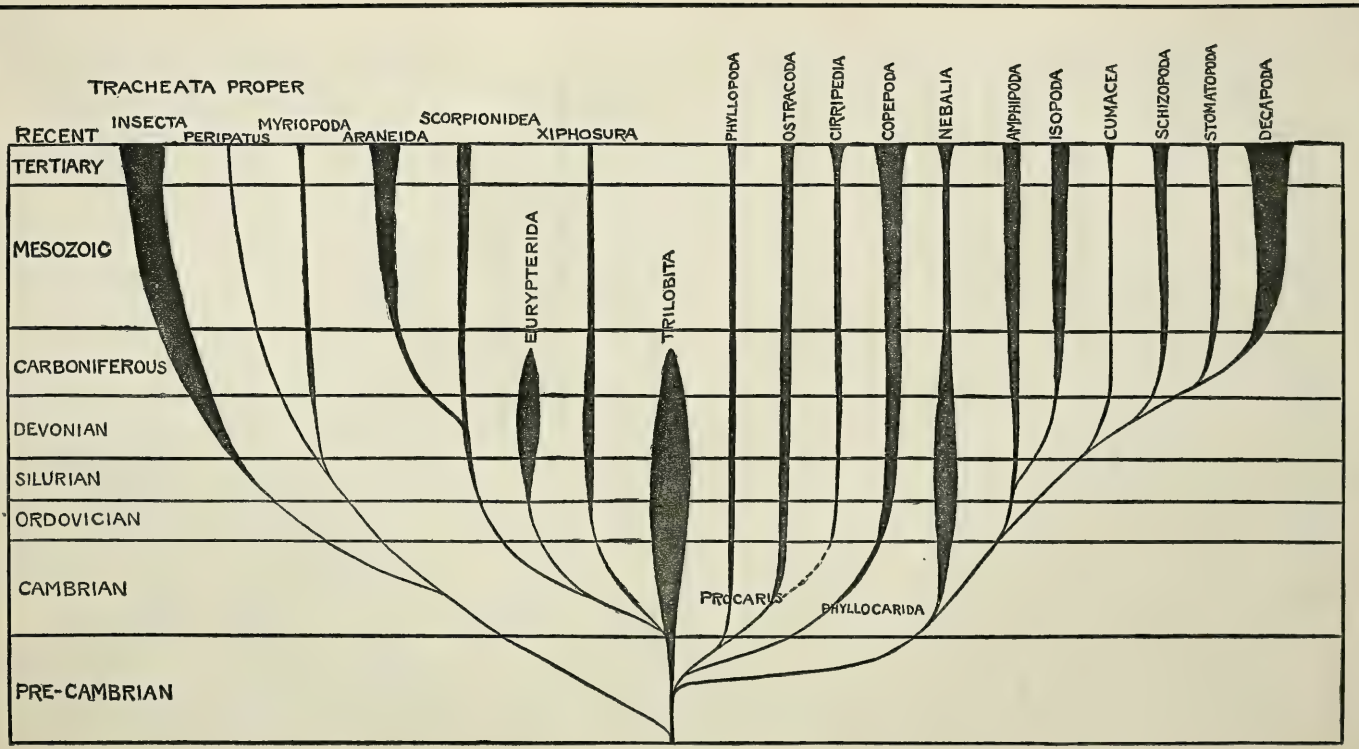
The faint beginnings of other great groups were also indicated, such as the macrouran-decapods represented by *Anthrapalæmon* and other forms in the Coal Measures; the stomatopods by *Pygocephalus Cooperi*, the amphipods by *Gampsonyx*, both in the Coal Measures; and by *Prosoponiscus* in the Permian.

Lastly, the Cirripedia, by the anomalous form made known in 1865,[2] under the name of *Turrilepas*, from the Wenlock Limestone.

In November 1866, I laid before this Society the evidence upon which I based my arrangement of the *Pterygoti* and *Limuli* in one order, for which I adopted Dana's very appropriate name of Merostomata (or 'thigh-mouthed' animals)—expanded to include all those ancient crustaceans comprehended in the two suborders of Eurypterida and Xiphosura and forming two groups of long-bodied and short-bodied forms, quite parallel to the Brachyoura and Macroura in the Decapoda; even the intermediate forms—corresponding to the Anomoura—being paralleled by the Hemiaspidæ (*Hemiaspis*, *Pseudoniscus*, etc.). This group formed the subject of

[1] Engraved and published by J. W. Lowry, and sold by J. Tennant, Strand.

[2] Quart. Journ. Geol. Soc. vol. xxi. pl. xiv. p. 486.



The Evolution of the Arthropoda in Geological Time.

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a monograph published by the Palæontographical Society (1865–1878, pp. 263, pl. xxxvi.), comprising 17 genera and 84 species—69 of which are Palæozoic in age. Writing to me, in Nov. 1867, Prof. Huxley says: 'I am a convert to the Merostomata in your sense.'

The integrity of this group, founded on the researches of Huxley, Salter, Dana, Hall, and many others besides myself, has been maintained, although many attempts have since been made to detach it from the crustacea and place it with the arachnida. For instance, it was proposed by Dr. Dohrn, in 1871,[1] to include the merostomata in a still larger division, under Haeckel's term Gigantostraca, which was made by expansion to embrace the merostomata and the trilobita, and to be placed *between* the crustacea and the arachnida.

Against this classification I urged that these animals, more especially the trilobita, being certainly amongst the earliest forms of crustacea with which we are acquainted, cannot be removed from that class without destroying its ancestral record. In arguing for their retention before this Society in 1871 (Quart. Journ. Geol. Soc. vol. xxviii. pp. 46–62) I wrote:—'Take away the trilobita from the pedigree of the crustacea, and I submit that one of the main arguments in favour of evolution to be derived from the class, so far from being strengthened, is destroyed. From what are the crustacea of to-day derived? Are we to assume that they all descended from the phyllopods and ostracods—the only two remaining orders whose life-history is conterminous with that of the trilobita? Or are we to assume that the arachnida are the older class?' 'If' (says Fritz Müller) 'the crustacea, insecta, myriapoda, and arachnida are indeed all branches of a common stock, it is evident that the water-inhabiting and water-breathing Crustacea must be regarded as the original stem from which the other terrestrial classes, with their tracheal respiration, have branched off.'

In the above-quoted paper (*op. cit.* p. 53) I pointed out that the young *Limulus*, when it quits the egg (at its 10th stage), has the hinder body as large as the head-shield, and the nine segments composing it are most clearly marked out, the abdominal spine being quite rudimentary and forming in fact the 9th segment. This is the so-called '*Trilobiten-stadium*' (Trilobite-stage) of Dohrn.

[1] 'Zur Embryologie und Morphologie des *Limulus polyphemus*,' von Dr. Anton Dohrn, Jenaische Zeitschrift, vol. vi. Heft 4, p. 580, pls. xiv. & xv.

"At this stage," says Packard, "the young swim briskly up and down, skimming about *on their backs* by flapping their gills, not bending their bodies." This locomotion of the young *Limulus*, by swimming upon its back, near the surface of the water (by means of its gill-feet), agrees very closely with the habit of *Apus*, of *Chirocephalus*, and *Artemia*, and is extremely suggestive of its affinity to the phyllopoda, with which, at this stage of its existence, it has many points in common, as well as with the trilobita.

It is interesting to notice that the Xiphosura (king-crabs)—which form the surviving representatives of this ancient order of the Merostomata, and are so widely distributed in the Coal Measures of North America, Britain, etc.—have likewise been discovered as far back in time as the Upper Silurian of Lanarkshire, being represented by a small form which I named and described, in 1868, as *Neolimulus falcatus*, having eight thoracic segments apparently free and movable, but wanting the tail-spine, which probably was developed later in life, or may have been represented by an extremely short terminal plate, as we see is the case in the young larval *Limulus*.[1] Thus the earliest fossil king-crab known probably resembled closely the free-swimming larva of the living king-crab as it leaves the egg.

I shall have occasion to refer again to the characters of *Limulus* when speaking of our present knowledge of the trilobites.

As to whether the Eurypterida—with their evidently aquatic branchiated respiration, their jaw-feet provided with swimming- (not walking-) extremities—are in the direct line of ancestral relationship to the recent scorpions, I may refer again to my paper [2] 'On some Points in the Structure of the Xiphosura,' etc.:—'This is one very strong argument, to my mind, in favour of the higher zoological position of *Pterygotus*—that, being extremely larval in its anatomy, it consequently possessed the capacity for further development, and so has been modified and disappeared'—its latest representatives being met with in the Coal Measures, where the then earliest known examples of fossil scorpions had also been found. But the discovery, almost simultaneously, by Thorell and Lindström in Gotland; by B. N. Peach in Scotland; and by Whitfield in North America (in 1885) of actual pulmonated land-scorpions in rocks of Upper Silurian age (as far back, in fact, in geological time as the earliest-known occurrences of *Pterygotus*, *Slimonia*, and *Eurypterus*) indicates that

[1] Geol. Mag. vol. v. (1868) pl. i. p. 1.

[2] Quart. Journ. Geol. Soc. vol. xxiii. (1867) p. 35.

the air-breathing scorpions were derived from a still earlier and as yet undiscovered aquatic progenitor, possibly in Cambrian or pre-Cambrian times.

Simultaneously with the commencement of my own work on the Merostomata, J. W. Salter undertook a monograph on the British Trilobites for the Palæontographical Society in 1864, of which four parts appeared—from 1864–1867. This work occupies 224 pages of letterpress, illustrated by 31 quarto plates, and contains descriptions of 114 British species (leaving about 200 more to be described). No one who takes up this fine work of our old friend can avoid a feeling of regret that Salter's valuable life and splendid palæontological knowledge should not have been longer spared to us to carry on to its completion this most important service.

One cannot help also imagining the joy with which so enthusiastic and earnest a worker as Salter would have welcomed and revelled in the recent discoveries of the long-sought appendages of the trilobites, which, alas! he did not live to see.

In 1864 he observed:—'Every author who has written on trilobites has more or less perceived their analogy with the *Limulus* or King-crab, to which tribe there is, indeed, a good deal of external resemblance. But this resemblance totally fails when we examine the under side of the animal; for all the researches hitherto made (and they are many) fail to detect the slightest traces of limbs in the trilobite.' . . . . . 'It is impossible, seeing the state of preservation in which they occur, to suppose that in every case—in fine shale, in limestone, in arenaceous mud—all traces of these organs should have been lost, had they ever existed. We are compelled to conclude that trilobites had not even membranaceous feet, and that the ventral surface was destitute of appendages.' (*Op. cit.* p. 9.) Fortunately, these long-sought organs have now been discovered.

Following up the progress of our knowledge of the trilobites, I may note that Dr. Henry Hicks made his first communication to this Society in 1865 on the genus *Anopolenus*, and between 1871 (when he came to London from the happy hunting-grounds of St. David's and joined the Geological Society) and 1876, he communicated to this Society a series of papers on the faunas of the 'Menevian,' the Lingula Flags, Tremadoc Slates, and Arenig series, giving descriptions of no fewer than 34 species of trilobites, belonging to 18 genera, from those ancient rocks.

But numerous as are these additions to our knowledge of the trilobites of Wales, they only represent a part of Dr. Hicks's discoveries, many of which were announced by Salter; the most important being that of the finding of a large *Paradoxides* at St. David's,[1] proving the existence of a Middle Cambrian or '*Paradoxides*-zone,' co-extensive with the vast area over which these early rocks have been observed, and occupying a persistent horizon throughout Europe and America.

A brief reference must here be made to the papers published by that excellent geologist and naturalist, the late Thomas Belt, F.G.S., in 1867 and 1868, on new trilobites from the Upper Cambrian rocks of North Wales, and on the Lingula Flags or Ffestiniog group of the Dolgelly District,[2] with figures and descriptions of four species of *Olenus* (non *Conocoryphe*) and four species of *Agnostus* from Dolgelly.

In 1888 I was so fortunate as to be able to record the first discovery of trilobites (*Conocoryphe viola*) in the Longmynd Group, Penrhyn quarries, Bethesda, near Bangor, in North Wales.[3]

The remarkable fauna of the *Olenellus* or Lowest Cambrian zone, originally discovered in America by Dr. Emmons in 1844, was first recognized in Europe by the late Dr. Linnarsson in 1871, in the basal zones of the Cambrian near Lake Miösen in Norway, but its typical genus *Olenellus* was then referred by him to the allied but more recent genus *Paradoxides*. This reference was corrected by Prof. Brögger in 1875; and the various brilliant papers on the Primordial formations by this author have given the *Olenellus*-fauna a marked and peculiar interest. In 1882 Linnarsson next made known the existence of the *Olenellus*-fauna in Scania, at the base of the Swedish Cambrian. In 1886 the same fauna was detected by Mickwitz in the Lower Cambrian of Russia (Esthonia), and this Russian fauna was figured and described in detail by Dr. F. Schmidt, of St. Petersburg. In 1887 Dr. Holm reported the existence of the *Olenellus*-fauna in the Cambrian of Lapland, where it was first detected by Mörstell in 1885. Thus the existence of this remarkable fossil group, the oldest well-marked fauna recognized by geologists in the Lower Cambrian, had already been demonstrated, in 1888, in three main regions, namely:—(1) in the region of the Rocky Mountains; (2) in the region of North-

[1] Quart. Journ. Geol. Soc. vol. xix. (1863) p. 274.

[2] Geol. Mag. 1867, p. 294, pl. xii. pp. 493 & 536; & *ibid.* 1868, p. 5, pl. ii.

[3] Quart. Journ. Geol. Soc. vol. xliv. (1888) pl. iv. pp. 74–78.

eastern America; (3) in the region drained by the Baltic Sea. Up to 1888 no recorded account of the discovery of *Olenellus* from the British Isles had been published, the oldest fauna described being the overlying *Paradoxides*-zones or Middle Cambrian formation.

The first recognizable traces of *Olenellus* in Britain were discovered by Prof. Lapworth in 1885. Further collections were made in 1887 and 1888, on the flanks of Caer Caradoc, Shropshire, and the species was named, in honour of Dr. Charles Callaway, *Olenellus Callavei*. Later on it was figured and described in the Geological Magazine for 1891.[1]

In August, 1891, Sir A. Geikie announced, at the British Association Meeting in Cardiff, the discovery of *Olenellus* by Messrs. Peach and Horne, in blue-black shales, a few feet below the 'Serpulite Grit' of the Cambrian rocks of North-west Scotland, in the Dundonnell Forest district of Ross-shire. The description of 'the *Olenellus*-zone of the North-west Highlands' formed the subject of a most valuable paper by Messrs. Peach and Horne, read before the Geological Society on the 10th February, 1892, and a new species of *Olenellus* is described and named *O. Lapworthi* by these authors.[2] Mr. B. N. Peach, F.R.S., communicated a second paper, 'Additions to the Fauna of the *Olenellus*-zone of the North-west Highlands,' on the 20th June, 1894; in which, in addition to *O. Lapworthi*, he describes and figures *O. Lapworthi* var. *elongatus*, *O. reticulatus*, *O. gigas*, *O. intermedius*, and *Olenelloides armatus*.[3]

'The Fauna of the Lower Cambrian or *Olenellus*-zone' forms the subject and title of an admirable monograph by Mr. C. D. Walcott, F.G.S.,[4] which, with the exception of the subsequent discovery of an *Olenellus*-fauna in the Lower Cambrian of the Scotch Highlands (already referred to), gives us a very complete and up-to-date account of this interesting and oldest fauna.

About 18 widely distributed localities are shown on the map of North America from British Columbia to Labrador, and as far south as Texas; whilst in Europe we have Spain, N. and S. Wales, the Scottish Highlands, Norway, Sweden, Finland, Bohemia, Bavaria, Podolia, Sardinia, Petchoraland, and the Ural Mountains.

Omitting trails, burrows, and tracks, the *Olenellus*-fauna has yielded 55 genera of organisms, 15 of which are trilobites.

[1] Geol. Mag. 1891, p. 529, pls. xiv. & xv.

[2] See Quart. Journ. Geol. Soc. vol. xlviii. (1892) pp. 227–242, pl. v.

[3] *Ibid.* vol. l. (1894) pp. 661–676, pls. xxix.–xxxii.

[4] Quarto, Washington, 1890, issued in 1891, pp. 264, with six engraved maps, 50 plates of fossils, and 26 illustrations in the text.

We may now add yet another locality in which this remarkable fauna occurs, as proved by the presence of the remains of *Olenellus* and the pteropod *Salterella*; namely in Western Australia, where it was discovered by Mr. Hardman in 1886.[1]

I must here refer to the discoveries of the limbs of trilobites. In 1870 the late E. Billings, F.G.S., the Palæontologist of the Geological Survey of Canada, brought before this Society and described a specimen of *Asaphus platycephalus*, from the Trenton Limestone of Ottawa, Canada, exhibiting remains of eight pairs of limbs, corresponding with the eight free and movable segments of the body, and showing the hypostome still attached to the doublure of the anterior border of the cephalic shield; traces of two appendages under the caudal shield were also visible.

On that occasion I exhibited a specimen of *Asaphus* from the same locality and horizon, showing evidence of a small 7–8-jointed palpus lying at the side of the hypostome apparently in its original position. After some remarks on the superficial characters of trilobites, I added:—'The prominence of the hypostome in the trilobita reminds one even more strongly of the genus *Apus* than of the isopods, and it is quite reasonable to expect in the trilobita a more generalized type of structure than that which marks the modern representatives of the class.'[2]

In 1881, after many years of untiring labour, Charles D. Walcott, F.G.S.,[3] furnished most conclusive proofs of the existence of appendages to the cephalic, thoracic, and abdominal divisions of *Calymene*, *Ceraurus*, and *Acidaspis*. His researches have been carried on by the method of making thin transverse and longitudinal sections[4] of rolled-up specimens. He has shown that the ventral body-wall of the trilobites was bounded inferiorly by a thin chitinous membrane, which was attached to the lower margin of the dorsal exoskeleton all round. This ventral membrane was supported by calcified arches, which gave attachment to the appendages beneath. He further established the existence of a row of articulated cylindrical limbs, on each side of

[1] Geol. Mag. 1890, pp. 98–106, A. H. Foord, on *Salterella Hardmani*, pl. iv. figs. 1, 1 *a*, 1 *b*, and *Olenellus Forresti*, *ibid.* pl. iv. figs. 2, 2 *a*, 2 *b*. Lower Cambrian, Kimberley District, Western Australia.

[2] Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 488.

[3] In 'Bull. Mus. Comp. Zool. Harvard, vol. viii. p. 6 & pp. 191–224.

[4] Of which he has had over 2000 thin sections prepared.

the middle line. Walcott described the thoracic appendages in *Calymene* as slender six-jointed walking-legs (endopodites) with a single pointed termination, the basal segment giving rise to a branch appendage (exopodite). On each side of the thoracic cavity he also described a row of bifid spiral appendages, of the nature of gills, and he suggested that branchiæ were attached to the bases of the thoracic limbs as well. The abdominal or pygidial rings carried appendages, a pair to each segment, but they do not appear to have differed from the thoracic limbs, save in size. The mouth is situated behind the hypostome, and has four pairs of jointed manducatory organs, the bases of which are modified to serve as jaws; the hindmost pair being the largest, and expanded at the distal extremity into a swimming-organ.

The correctness of Billings's views, as to the nature of the thoracic limbs of *Asaphus platycephalus*, was further confirmed by the finding of a specimen of *Asaphus megistos*, in the Ordovician rocks of Ohio, which shows the under surface with its appendages, and has been described by Dr. I. Mickleborough.[1] This specimen shows two pairs of maxillipeds or jaw-feet, eight pairs of walking-appendages, corresponding to the eight pairs of free thoracic segments, each limb having about six joints. The under side of the coalesced segments of the abdomen (pygidium) reveals a series of from 12 to 16 similar paired appendages, diminishing rapidly in size from before backwards to the extremity. A broad median groove extends along the under side of the thorax and abdomen, and probably represents the space once occupied by the sternites or, possibly, the straight intestinal canal, observed by Barrande in some trilobites from Bohemia. Traces of supposed branchial filaments have also been observed in this specimen, apparently attached to the thoracic legs.

No further addition had been made to our knowledge of the appendages of trilobites until July 1893, when Mr. W. D. Matthew, a student of Columbia College (N.Y.), communicated the result of his examination of several specimens of *Triarthrus Beckii*, obtained by Mr. W. S. Valiant from the 'Hudson River Shales' (Ordovician), near Rome, New York.[2] After recording the extent of our

[1] Journ. Cincinnati Society Nat. Hist. vol. vi. (1883), & Geol. Mag. 1884, p. 80.

[2] See Trans. New York Acad. Sci. vol. xii. (1893) pp. 237–241, pl. viii., 'On Antennæ and other Appendages of *Triarthrus Beckii*,' by W. D. Matthew, July 17th, 1893.

previous knowledge derived from the important researches of C. D. Walcott, he proceeds to describe the additions which the specimens from Rome have supplied. These trilobites are found in a soft, fine, black shale, and are perfectly well preserved. The most noticeable character is the presence of long, slender, many-jointed whip-like appendages attached to the front of the head, closely resembling the flagellate antennæ of other crustaceans. These originate close together, just beneath the centre of the anterior border of the head-shield, and are as long again, nearly, as the glabella itself. Mr. Matthew also was able to detect a series of walking- or swimming-legs, one a narrow, jointed, cylindrical leg, the other thin, broad, fringed with a comb-like structure similar to the gills of many crustacea.

The next communication is from Mr. C. E. Beecher, of New Haven, Conn., 'On the Mode of Occurrence and the Structure and Development of *Triarthrus Becki*.'[1] The material gathered for the Yale University (by the aid of Prof. Marsh) near Rome, New York, is probably some of the best which has been obtained, and has been carefully examined and described by Mr. Beecher.

In their present condition the specimens from Rome contain very little calcite, nearly the entire calcareous and chitinous portions of the trilobites being replaced by a thin film of iron pyrite. To this cause is doubtless due the preservation of delicate organs and structures which would otherwise have been destroyed.

The specimens thus preserved occupy an extremely restricted vertical distribution, but within this range they are nearly all complete and preserve their appendages. They are of all ages, from larval forms up to full-grown individuals, whilst the adjacent strata contain a rather sparse fauna in which the trilobites are generally fragmentary and without appendages. The author believes that, in the majority of beds in which trilobites are found, the remains met with represent the exuviæ of living animals that have cast their shell, rather than the tests of dead individuals. In this particular deposit the appendages are apparently in the position which they occupied during life, and not such as would be assumed in the cast-off shells of recent crustacea.

Mr. Beecher mentions another interesting point, namely, that nearly all the specimens are found with the back down, which is explained by suggesting that, although they lived with the ventral

[1] From the 'American Geologist,' vol. xiii. (January 1894) pp. 38–43, pl. iii.

side downwards, the gases in the viscera produced during decomposition were sufficient to overturn the animal and allow it to be buried by the accumulation of the fine sediments in the position in which it is now found.

The appendages of *Triarthrus* appear now to be very well made out. The antennæ, as seen in a number of specimens, were simple multiarticulate flagella, which Walcott in a later paper (Geol. Mag. 1894, p. 246, pl. viii. fig. 1 *e*) has shown extend backwards to the lateral margin of the hypostome, so that they occupy exactly the same position as do the first antennæ in recent *Apus*.[1]

Two small appendages, like simple palpi, with broad basal joints, which may represent the maxilla, are seen in one of Walcott's specimens, and there were probably four pairs of similar cephalic appendages, besides the simple flagellate antennæ, more or less modified to serve as mouth-organs.

No essential differences have been observed in the series of limbs attached to the (14 or 16?) free segments.

Each of these segments bears a pair of biramous appendages originating at the sides of the axis, as in other trilobites (e. g. *Asaphus*, *Calymene*, *Ceraurus*, etc.).

The anterior legs are the longest, and the others gradually become shorter towards the pygidium.

Each limb consists of two nearly equal branches, the 'endopodite' and 'exopodite,' which may be correlated with the typical crustacean primitive limb and are well displayed in the adult *Mysis*; in the biramose natatory-feet of the zoea of the common shore-crab (*Carcinus*); and retained in the appendages of the abdomen of the adult lobster (*Homarus*).

The 'endopodite,' or walking-limb, is composed of seven articulations, the first (coxopodite) or basal joint also giving origin to the 'exopodite,' or swimming-appendage.

The 'exopodite' has a long basal joint serrated on its lower border, broader at the proximal end and narrower at the distal extremity; here it terminates in a many-jointed flabellate appendage bordered with a thick fringe of setæ, which extend also along the serrated border of the basal joint.

Practically, these biramose limbs are reproduced along the entire series of free segments. The appendages belonging to the pygidium closely resemble the branchigerous feet of *Apus*, and evidently may be correlated with typical phyllopod limbs.

[1] See H. M. Bernard, Quart. Journ. Geol. Soc. vol. l. (1894) p. 425.

Walcott, in the Geological Magazine,[1] and H. M. Bernard, in the Quarterly Journal of this Society,[2] have given valuable additional contributions on the appendages of trilobites and on their systematic position, which are most helpful and acceptable at this time.

The first point insisted upon by all systematic zoologists—long before the finding of appendages had thrown so much new light upon our investigations—was that the great variability in the number of the segments in trilobites was a feature which distinctly connected them with the phyllopoda.

Bernard considers of greater importance still the gradual diminution of the size of the segments posteriorly, which remarkable feature the trilobites share with *Apus*.

I would also call attention to the fact that those earlier trilobites which best exhibit this large number of segments, such as *Olenellus*, *Paradoxides*, etc., are likewise remarkable for the simplicity and exact similarity of their segments, being a serial repetition of one another, and even the coalesced segments forming the head-shield share the same resemblance with the free posterior thoracic and abdominal ones.[3]

This was long ago designated by Owen as 'the vegetative repetition of parts,' and is most completely exemplified in the annelida and the myriopoda.

Bernard has given expression to the idea most aptly when he writes (*op. cit.* p. 412) :—'The adult is but the grown, not metamorphosed, larva—grown by the continual development of segments from before backwards, until at a certain stage this process becomes fixed, and we have the adult *Apus* with a number of fixed rudimentary segments. This fixation of a number of undeveloped segments is visible also in many trilobites.'

In the earlier forms (as *Olenellus*) these rudimentary posterior segments still remain free ; but as a rule they are coalesced to form the plate-like pygidium so characteristic of the trilobites.

Turning to the appendages, the simple multisegmented flagellate antennæ are extremely characteristic of the crustacea, being met with in lowly copepods and highly developed decapods.

The biramose paired limbs are quite a primitive type, like the

[1] 1894, pp. 246–251. [2] August 1894, vol. l. pp. 411–434.

[3] *Triarthrus* is essentially a 'Primordial' type that has retained its general simplicity of structure, although it has continued on until Upper Ordovician time.

segments to which they are attached, exceedingly simple, yet characteristic; and with the exception of the antennæ and the four succeeding pairs of appendages, which are modified to serve as mouth-organs (maxillæ and maxillipeds), the whole series are simple biramose natatory or walking-feet, such as persist still in adult *Mysis* and many other recent crustacea.

The eyes in trilobites closely resemble those of other arthropods, but vary somewhat in position and also in development, in some genera the eyes being altogether absent, as in *Ampyx*, *Ceraurus*, etc., whilst in others, like *Æglina*, they are enormously exaggerated in size. In some genera the eyes are hyaline, the faceted surface being covered with a fine transparent layer, whilst in others the facets appear prominently on the surface. It is suggested by Bernard that the minute pore observed in the head, near the compound eye in several genera (*Trinucleus*, *Acidaspis*, *Calymene*, *Ampyx*, *Griffithides*, *Phillipsia*, etc.), may be analogous to the pore in the head-shield of *Apus* and be the opening into the water-sac covering the eyes; and whilst in some genera of trilobites this water-sac may have existed, it may have degenerated in others, leaving the eye in contact with the outer cuticle, which covered it like a thin transparent membrane.

In none of the trilobites have larval eye-spots been observed.

Dr. Lang[1] held the view (in 1891) that if a fifth pair of cephalic limbs were found comparable with the anterior antennæ, trilobites might then be regarded as primitive entomostraca, to be derived from the same racial form as the phyllopoda. I venture to think it highly probable that the simple multiarticulate antennæ of *Triarthrus* are the anterior antennæ[2] and not mouth-organs, and that four pairs of gnathopodites exist in addition to them.

Walcott is of opinion that the trilobita formed a distinct branch, which diverged at a very early date from the phyllopoda, and having expended its vital energy in Palæozoic times it disappeared. He adds: 'Probably two thousand species and one hundred or more genera are known from Palæozoic strata. With this great differentiation the initial vital energy of the group became impaired, and the trilobita died out at the close of Palæozoic time.' He even proposes to keep the trilobita and the merostomata

[1] 'Text-book of Comparative Anatomy,' English edition, 1891, p. 415.

[2] C. D. Walcott's figure (Geol. Mag. 1894, pl. viii. fig. 1) is by no means conclusive as to the exact position of these simple antennæ, and possibly their point of attachment may be found to be *in front* of the mouth. But in *Apus*, *Nebalia*, and also in all *Nauplius* larvæ they are attached at the sides of that structure. The point, therefore, is immaterial.

apart as two distinct classes. There does not appear to me, however, to be sufficient reason given for arbitrarily separating these orders from the class Crustacea, of which, in Palæozoic times, they certainly formed a perfectly natural and homogeneous part.

I am quite willing to adopt the view that the trilobita are ancestrally connected with *Limulus*; that *Limulus* may be related through *Hemiaspis* with *Eurypterus*; but all the intermediate forms have not yet been met with. That some ancestral Eurypterid must have given rise to *Scorpio* cannot, I think, be doubted; but it must have been in pre-Silurian times, for Peach and Lindström's *Palæophonus* had already appeared in the Upper Silurian of Lanarkshire and Gotland as a terrestrial pulmonated form, while a similar land-scorpion had been discovered by Whitfield in the Silurian of America.

The Phyllopoda deserve consideration from a geological standpoint, a representative of *Apus* having been met with in the Lower Cambrian (*Protocaris Marshii*) of Vermont, U.S. Some of the living genera are naked (*Branchipus* and *Artemia*), but in most the front portion of the body is protected by a shield-like carapace (*Apus*), or it may be enclosed, as in *Estheria*, in a bivalve shell.

The fossil remains of these bivalved phyllopods of the genera *Estheria* and *Leaia* were described by Prof. T. Rupert Jones as far back as 1862 in the Palæontographical Society's volume xiv. (for 1860), where he figures and describes 19 species ranging from the Old Red and Carboniferous upwards.

The most ancient of these shield-bearing crustaceans, originally placed with the phyllopoda and having a single modern analogue (*Nebalia*), have now, by general consent, been removed and placed under the order Phyllocarida, a name suggested by Dr. A. S. Packard in 1879 ('American Naturalist,' vol. xiii. p. 128).

The fossil forms referred to this order were originally studied and noticed by M'Coy, Salter, Barrande, Clarke, and myself, and have subsequently been fully described in the volumes of the Palæontographical Society by Prof. T. Rupert Jones and myself (1888 *et seq.*).

Metschnikoff, who studied the embryology of *Nebalia*, considered it to be a 'phyllopodiform decapod.' Besides the resemblance to the decapods, there is also a combination of copepod and phyllopod characteristics. The type is an instance of a generalized form, and is of high antiquity, having made its appearance in Cambrian times,

when there lived (if we regard the relative size of most crustacea, and especially that of the living *Nebalia*) gigantic forms. Such was the Silurian *Ceratiocaris ludensis*, which was probably more than 2 feet in length.

The modern *Nebalia* is extremely small, about $\frac{1}{4}$ inch in length,[1] with the body compressed, and the carapace bivalved, as in *Limnadia*, one of the genuine phyllopods. There is a large movable rostrum overhanging the head; stalked eyes; the cephalic portion carries two pairs of antennæ and three pairs of special mouth-organs (mandibles and maxillæ); the thoracic segments bear eight pairs of short, leaf-like respiratory-feet, which are followed by six pairs of (abdominal) simple swimming-feet, four being large and two rudimentary, while the last two segments (7th and 8th) are destitute of appendages, the body terminating in an elongated phyllopod-like caudal fork. Compared with *Nebalia*, the fossil forms give evidence of an articulated rostrum; traces of antennæ; the presence of a pair of strong mandibles; of a large expanded shield in some, and of a folded or bivalved carapace in others; of the presence of seven or eight body-segments, sometimes carrying branchigerous appendages, the terminal segment carrying a central caudal spine (telson) and two lateral shorter ones (stylets).

It seems highly probable that the old giant pod-shrimps (*Ceratiocaris*, *Dithyrocaris*, etc.), whose remains occur in the Palæozoic rocks from the Cambrian to the Carboniferous, are represented by the minute living *Nebalia*, and that these early forms may have given rise to, and have been the forerunners of, the modern Malacostraca. "In *Nebalia*," says Claus, "we probably have to do with an offshoot of the phyllopod-like ancestors of the malacostraca, which has persisted on to the present time."

Turning to the other phyllopodous entomostraca: so far as the evidence borne by the carapace can be accepted, the genus *Estheria* existed in the fresh and brackish waters of the Devonian Period, in Livonia, Caithness, and Orkney, and also in Nova Scotia and Scotland. It flourished in the European area at several of the Upper Carboniferous stages, and was well represented in the Secondary and Tertiary rocks; it is also living to-day and has a world-wide distribution.

The Phyllocarida seem in some cases to afford examples of persistency of type, and in others of local or temporary specialization. One of the oldest known is the Cambrian *Hymenocaris*, a prototype

[1] A newly-described species, *Nebaliopsis typica*, Sars, measures as much as $1\frac{3}{8}$ inch.

of the recent *Nebalia*. *Caryocaris* of the Arenig series possibly belongs to the same group; and the Upper Silurian *Ceratiocaris* carries the form to a high degree of perfection; but until we meet with the *Nebalia* of to-day we have no tangible links in this series in intermediate geological times.

So also one of the oldest forms, Walcott's Cambrian *Protocaris*, is quite susceptible of being regarded as a predecessor of the living *Apus*. The Carboniferous *Dithyrocaris* and its allies stand probably in the relation of genealogical links.

But much more research among these interesting lower crustacean fossils is required before their phylogenetic relationship can be fully elucidated.

The Ostracoda, which have the entire body enclosed in a shell or carapace composed of two valves united along the back by a membrane (represented by such forms as *Cypris*, *Cypridina*, *Candona*, *Beyrichia*, *Primitia*, etc.), are chiefly dwellers in shallows, and occur both in fresh and salt water; they are usually of minute size; but there are deep-sea types which attain comparatively large dimensions (an inch long). They are met with in rocks of almost all ages from the Cambrian upwards. To speak of them here is to recall the nearly lifelong labours (from about 1840) devoted to their elucidation by Prof. T. Rupert Jones, who has described many hundreds of these primitive crustacea from rocks of every British formation as well as from very many foreign countries.

Great as are the transformations which these organisms have witnessed in the long cycles of geological change from Lower Cambrian to modern time, they present, nevertheless, a general facies, and (like the genus *Lingula* amongst the brachiopoda) must be looked upon as one of those persistent types which possess enormous power of multiplication, so that entire beds of rock may be said to be composed of their microscopic tests. The living species also possess exceptional powers of endurance and provision for the preservation of their lives in periods of drought, often retaining their vitality in a dormant state perhaps for years; thus they have persisted through all the vicissitudes of geological time, represented by the entire succession of the stratified rocks: 'all things changing, but themselves unchanged.'

Prof. T. Rupert Jones writes:—'Among the Palæozoic ostracoda, the simply smooth and oblong bivalved carapaces of the early *Aparchites* lead to more or less Leperditioid forms, some with slight

nuchal furrow, some also with vascular muscle-spot and ocular tubercle. These features evidently have reference to structural modifications of considerable biological value. *Leperditia* kept them until the period of the Great Carboniferous Ocean (Mountain Limestone); but in the subsequent lagoons of the Coal Measures this genus lost its best characters and died out.

'*Primitia*, another simple form, contemporaneous with the first mentioned, had the nuchal (dorsal) furrow for its chief character; but this was soon masked by the swollen edges of the sulcus, indicative of an approach to the form of the Silurian *Bollia* and *Beyrichia*; the latter died out in the Carboniferous period.

'Of these three types, there are very numerous modifications, varying from the simply undulate surface of the first to the multilobed *Beyrichiæ* and intricately-sculptured *Octonaria* and *Strepula*. What the biological significance of the several lobes and lobules may be is not clear, especially of the hypertrophied antero-ventral lobe of some of the *Beyrichiæ*.

'From *Primitia*, with its dorsal notch, we may also derive *Entomis*, with its deep transverse sulcus, and other forms in which this feature dwindles to a subcentral pit, as in *Kirkbya* and *Barychilina*. In some of these the carapace becomes much ornamented. Some have a strong reticulation, and some a linear or curved striation. These sculpturings pass from one to the other by means of cross-lines, between the longitudinal costulæ, forming meshes. *Kirkbya* ranges from the Lower Silurian to the Permian, where it ceases; *Barychilina* has been found in the Lower Silurian and Devonian.

'None of the older genera exist now; but some of the existing forms of the Cypridide, Cytheridæ, and Cytherellidæ are fully represented by predecessors in the Palæozoic rocks. The wonderfully well-preserved *Palæocypris Edwardsii* (C. Brongniart), enclosed in transparent silica, displaying the soft parts of the animal as perfect as in life, from the Coal Measures of St. Étienne, is evidence of the existence of Cyprids in that far-off time. *Carbonia* may possibly be a near ally; at all events there are *Macrocypris* and other members of the group, including the almost ubiquitous *Bairdia*, the former ranging from the Lower Silurian to the present day, and the latter from the Devonian upwards. Near the last-mentioned genus are Ulrich's *Beecherella* and *Krausella*, both of Palæozoic age only.

'Many diverse forms related to *Cypridina* flourish at present in the warm seas of different regions, near the surface-waters. Judging

from various shapes of the bivalved carapace, with its peculiar hood and antero-ventral notch (for the free movement of the antennæ), more or less expressed, we have Cypridinads in the Lower (and Upper ?) Silurian, Devonian, especially in the Carboniferous (very many in the Mountain Limestone and several in the Coal Measures), and rare in the Permian. *Cypridinæ* occur also in Cretaceous and Tertiary formations.

'Why some ostracoda of somewhat specialized structure such as *Leperditia* should have come into existence in the Upper Silurian, and continued in nearly the same form for a few millenniums only, while others like *Cypridina*, also of good standing, should have begun even earlier, and lasted on, with diverse modifications, through many more millenniums, is difficult to explain, except on the hypothesis that the latter genus was enabled to have more variations and adaptations to fit it for changing conditions of the sea. In this case it could not have been so highly specialized as its earlier cousin-german, nor does it seem to have yet given up its more generalized structure for the specialized advancement which precludes more marked and fundamental changes.'

I have endeavoured to depict on p. lxxi. the evolution of the arthropoda in geological time, and also, by means of diagrams, to illustrate some of the leading forms of which I have spoken.

In concluding this brief excursion over the abysses of Palæozoic time, I have only been able to bring under your notice a few isolated points of interest in the crustacean fauna which lies in the depths of these ancient deposits. They may, however, serve to show that this group of lowly existences is not destitute of interest for the biologist. There may also be a possibility of connecting these isolated observations so as to show their bearing upon the greater question of the development of life.

In order, however, to do this effectively I must ask you to accompany me next year in a second excursion over the newer Palæozoic and Kainozoic seas, where, nearer land and in shallower waters, we shall find a still greater variety of life-forms to study.

Two conclusions may be drawn from our observations, namely, (1) that the ancient faunas of the earth were far more widespread, more simple and more uniform than are our recent faunas ; and (2) if, as the researches of geologists seem to indicate, other sedimentary rocks exist, *older* than the Lower Cambrian, then we may hope to

gather evidence of still earlier and more simple forms of life than are met with in the '*Olenellus*-zone.' We are fully justified in concluding that such must actually have existed, because we find in the Lower Cambrian evidence of a quite considerable fauna belonging to several divisions, which, although lowly in themselves, are nevertheless already so clearly differentiated one from the other as to prove to us that we are still, both biologically and chronologically, very far removed from the commencement of life on the earth.

February 20th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

The Rev. George Charles Hungerford Pollen, S.J., Stonyhurst College, Blackburn, Lancashire; Charles Rollin, Esq., Jesmond, Newcastle-on-Tyne; and William Pinckard Delane Stebbing, Esq., 169 Gloucester Terrace, Hyde Park, W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced to the Fellows the grievous loss which the Society had suffered in the decease of its Foreign Secretary, Mr. J. W. Hulke, F.R.S., President of the Royal College of Surgeons. He dwelt on the great value of Mr. Hulke's work in Vertebrate Palæontology, on his long services as a Member of Council and an Officer of the Society, and on his amiable personal qualities, which had endeared him to a wide circle of friends. He read the following resolution which the Council had that afternoon unanimously voted, and communicated to Mrs. Hulke with the expression of their heartfelt sympathy: "That this Council most deeply deplore the sad loss that the Society and all those interested in palæontology have sustained by the untimely decease of our Foreign Secretary, Mr. J. W. Hulke, F.R.S., whose investigations in various branches of science have led to such valuable results."

The following communications were read:—

1. 'Contributions to the Palæontology and Physical Geology of the West Indies.' By J. W. Gregory, D.Sc., F.G.S.

2. 'The Whitehaven Sandstone Series.' By J. D. Kendall, Esq., F.G.S.

3. 'Notes on the Genus *Murchisonia* and its Allies, with a Revision of the British Carboniferous Species, and Descriptions of some New Forms.' By Miss J. Donald. (Communicated by J. G. Goodchild, Esq., F.G.S.)

The following specimens were exhibited:—

Specimens of Corals from San Domingo, exhibited from the Society's Museum in illustration of the paper by Dr. J. W. Gregory, F.G.S.; also specimens and microscope-sections exhibited by himself for the same purpose.

Tertiary Mollusca from the Paris and Hampshire Basins, exhibited by G. F. Harris, Esq., F.G.S.

Specimens and casts of the Genus *Murchisonia*, etc., exhibited by J. G. Goodchild, Esq., F.G.S., on behalf of Miss J. Donald, in illustration of her paper.

A copy of a reduction of the Geological Map of Spain, scale $\frac{1}{400,000}$ in 16 sheets, in one sheet, scale $\frac{1}{500,000}$, presented by the Comision del Mapa geológico de España.

March 6th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Frank Baker, Esq., Vernon House, Canterbury; and Charles A. V. Butler, Esq., Isthmian Club, Piccadilly, W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that the International Geographical Congress will meet in London during the first week in August, and will be attended by a large number of Delegates of Foreign Governments and Societies. A subscription of £1 constitutes Membership. Subscriptions, and Donations to the Reception Fund, are now being received by the Secretaries of the International Geographical Congress, 1 Savile Row, London, W.

The following communications were read:—

1. 'A new Ossiferous Fissure in Creswell Crags.' By W. L. H. Duckworth, Esq., and F. E. Swainson, Esq. (Communicated by Prof. T. M°K. Hughes, M.A., F.R.S., F.G.S.)

2. 'Notes on the Chemical Composition of some Oceanic Deposits.' By Prof. J. B. Harrison, M.A., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

The following were exhibited:—

Mammalian remains, Flint and Quartzite Implements, etc., exhibited by Messrs. W. L. H. Duckworth and F. E. Swainson in illustration of their paper.

Specimen showing Upper and Lower Maxilla of *Pachyrhizodus Gardneri*, from the Lower Chalk of Burham, Rochester, exhibited by G. E. Dibley, Esq., F.G.S.

Horizontal Section 148. England and Wales, and Horizontal Section 35. Ireland, presented by the Director-General of H.M. Geological Survey.

March 20th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

R. Neil Smith, Esq., M.A., Hill End, New South Wales, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On Fluvio-Glacial and Interglacial Deposits in Switzerland.' By C. S. Du Riche Preller, M.A., Ph.D., F.G.S., F.C.S., A.M.I.C.E., M.I.E.E.

2. 'The Bajocian of the Mid-Cotteswolds.' By S. S. Buckman, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of Ammonites, etc., exhibited by S. S. Buckman, Esq., F.G.S., in illustration of his paper.

Specimen of Interglacial Lignite from Uznach and specimens of Fluvio-Glacial Pliocene Cavernous Nagelfluh, from Baden, Switzerland, exhibited by C. S. Du Riche Preller, M.A., Ph.D., F.G.S., in illustration of his paper.

A Special General Meeting was held at 7.45 o'clock p.m., before the Ordinary General Meeting, at which Sir John Evans, K.C.B., F.R.S., was elected Foreign Secretary, and Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., and Horace T. Brown, Esq., F.R.S., were elected Members of Council.

April 3rd, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Telford Edwards, Esq., Cowbridge, Glamorganshire, was elected a Fellow; and Dr. K. de Kroustchoff, St. Petersburg, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced that the Council had temporarily appointed Thomas Mercer and his wife to the respective posts of House Porter and Upper Housemaid.

The following communications were read :—

1. 'Physical Features and Geology of Mauritius.' By Major H. de Haga Haig, R.E., F.G.S.

2. 'On a Comparison of the Permian Freshwater Lamellibranchiata from Russia with those from the Karoo Formation of Africa.' By Dr. Wladimir Amalitsky, Professor of Geology in Warsaw University. (Communicated by Dr. Henry Woodward, F.R.S., Pres. Geol. Soc.)

3. 'Ice-plough Furrows of a Glacial Period.' By W. S. Gresley, Esq., F.G.S.

The following specimens were exhibited :—

Sketches of the Scenery and Flora of Mauritius, exhibited by Major H. de Haga Haig, in illustration of his paper.

Specimens from the Society's collection found in the Karoo Beds of South Africa, shown in illustration of Prof. Amalitsky's paper.

Copies of newly issued Geological Survey Maps, England, Sheets 102 N.W., S.W., S.E., Solid and Drift, presented by the Director-General of that Survey.

April 24th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Cyril Edward Parsons, Esq., Birdsall Grange, York ; and William Percy Workman, Esq., M.A., B.Sc., Burton House, Lansdowne, Bath, were elected Fellows ; and Magister Friedrich Schmidt, St. Petersburg, was elected a Foreign Member of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On the Shingle Beds of Eastern East Anglia.' By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

2. 'Supplementary Notes on the Systematic Position of the Trilobites.' By H. M. Bernard, Esq., M.A., F.L.S. (Communicated by Dr. Henry Woodward, F.R.S., P.G.S.)

3. 'An Experiment to illustrate the Mode of Flow of a Viscous Fluid.' By Prof. W. J. Sollas, D.Sc., LL.D., M.A., F.R.S., F.G.S.

The following specimens and maps were exhibited:—

Specimens of Shingle, etc., exhibited by Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S., in illustration of his paper.

Rock-specimens from the ballast of a Swedish vessel wrecked off Hunstanton two years ago, exhibited by Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

Tertiary fossils from Fyans Ford, etc., near Geelong, Victoria, exhibited by T. W. Reader, Esq., F.G.S.

Scratched Blocks from the Findelen Glacier, Zermatt, exhibited by W. W. Watts, Esq., M.A., F.G.S.

Copies of newly-issued Geological Survey Maps, England, Sheet 343, Solid and Drift, presented by the Director-General of H.M. Geological Survey.

May 8th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Charles Maidment, Esq., P.O. Box 48, Johannesburg, Transvaal, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The Secretary announced that a portrait of the late Leonard Horner, F.R.S., twice President of the Geological Society, was exhibited on the screen, and presented by Mrs. Katherine Lyall.

Prof. Judd drew attention to an interesting series of photographs sent for exhibition to the Geological Society by Prof. Liversidge, F.R.S., of Sydney, N.S.W. Prof. Liversidge has found that sections of gold nuggets, when etched with chlorine-water, exhibit lines like the Widmanstetten figures of meteorites, showing that the gold has a crystalline structure, octahedral and cubic forms being displayed. The very beautiful photographs on the table admirably illustrated this remarkable structure.

The following communications were read:—

1. 'The Stirling Dolerite.' By Horace W. Monckton, Esq., F.L.S., F.G.S.

2. 'Notes on some Railway-cuttings near Keswick.' By J. Postlethwaite, Esq., F.G.S.

3. 'The Shelly Clays and Gravels of Aberdeenshire considered in Relation to the Question of Submergence.' By Dugald Bell, Esq., F.G.S.

In addition to the portrait and photographs mentioned above, the following specimens were exhibited:—

Photographs, rock-specimens, and microscope-sections, exhibited by Horace W. Monckton, Esq., F.L.S., F.G.S., in illustration of his paper.

Specimens and microscope-sections of rocks from near Troutbeck, exhibited by J. Postlethwaite, Esq., F.G.S., in illustration of his paper.

Portrait in oils of the late Dean Buckland, F.R.S., twice President of the Geological Society. Recently purchased.

May 22nd, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Frederic Barke, Esq., Penton Villa, Stoke-on-Trent, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On a Human Skull and Limb-bones found in the Palæolithic Terrace-gravels at Galley Hill, Kent.' By E. T. Newton, Esq., F.R.S., F.G.S.

2. 'Geological Notes of a Journey round the Coast of Norway and into Northern Russia.' By G. S. Boulger, Esq., F.L.S., F.G.S.

3. 'On some Foraminifera of Rhætic Age, from Wedmore in Somerset.' By Frederick Chapman, Esq., F.R.M.S. (Communicated by Prof. T. Rupert Jones, F.R.S., F.G.S.)[1]

The following specimens, etc., were exhibited:—

Human Bones, flint-implements, and mammalian remains from the gravels of Galley Hill, exhibited on behalf of Mr. R. Elliott; and a hippopotamus-tooth from Milton Street, exhibited on behalf of Dr. F. Corner, by E. T. Newton, Esq., F.R.S., F.G.S.

Flint-flake and implements recently found at Galley Hill, exhibited by E. T. Newton, Esq., F.R.S., F.G.S.

Rock-specimens and photographs, exhibited by G. S. Boulger, Esq., F.L.S., F.G.S., in illustration of his paper.

Specimens exhibited by F. Chapman, Esq., F.R.M.S., in illustration of his paper.

Six specimens of quartz showing crystals of tetradymite (telluric bismuth) in association with gold, from Dunallan No. 1 Gold Mine, near Coolgardie, Western Australia, exhibited by A. O. Watkins, Esq., F.G.S.

A Bust of the late J. W. Hulke, Esq., F.R.S., For. Sec. G.S., by Walter Merrett, Esq.

June 5th, 1895.

W. H. Hudleston, Esq., M.A., F.R.S., F.L.S., Vice-President, in the Chair.

Arthur Wilkey Dymond, Esq., Assoc.R.S.M., 28 Palace Gardens Terrace, Kensington, W.; and Umfreville P. Swinburne, Esq., 39 Cadogan Square, S.W., were elected Fellows of the Society.

[1] Withdrawn by permission of the Council.

The names of certain Fellows were read out for the first time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On a well-marked Horizon of Radiolarian Rocks in the Lower Culm Measures of Devon, Cornwall, and West Somerset.' By George Jennings Hinde, Ph.D., F.G.S., and Howard Fox, Esq., F.G.S.

2. 'The Geology of Mount Ruwenzori and some Adjoining Regions of Equatorial Africa.' By G. F. Scott-Elliot, Esq., M.A., B.Sc., F.L.S., and J. W. Gregory, D.Sc., F.G.S.

3. 'On Overthrusts of Tertiary Date in Dorset.' By A. Strahan, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

The following specimens, etc., were exhibited:—

Rock-specimens, fossils, microscope-sections, and photographs, exhibited by G. J. Hinde, Ph.D., F.G.S., and Howard Fox, Esq., F.G.S., in illustration of their paper.

Rock-specimens and microscope-sections, exhibited by G. F. Scott-Elliot, Esq., M.A., B.Sc., F.L.S., and J. W. Gregory, D.Sc., F.G.S., in illustration of their paper.

Photographs and lantern-slides, exhibited by A. Strahan, Esq., M.A., F.G.S., in illustration of his paper.

Twenty-three pebbles of quartzite, greensand, sandstone, and felsite from the Upper Chalk of Northfleet, Gravesend, and from the Lower Chalk of Warlingham and Cuxton; abnormal specimen of *Echinocorys vulgaris* from the Lower Chalk of Warlingham, exhibited by G. E. Dibley, Esq., F.G.S.

Photograph of Boulder-Clay Cliffs, Carr Naze, Filey, presented by the Yorkshire Geological and Polytechnic Society.

June 19th, 1895.

Dr. Henry Woodward, F.R.S., President, in the Chair.

Frank Corner, Esq., M.R.C.S., L.R.C.P., Manor House, East India Road, Poplar, E.; Charles O. West, Esq., Sudbury, Suffolk, and 60 Aldermanbury, E.C.; and Claude Henry Chaloner Woodhouse, Esq., B.Sc., Assoc.R.C.S., 11 The Hill, Putney, S.W., were elected Fellows; Prof. W. Dames, Berlin, was elected a Foreign Member; and Dr. P. Groth, Munich, a Foreign Correspondent of the Society.

The following names were read out for the second time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions:—Rev. F. Ballard;

C. Browne, Esq.; D. Burns, Esq.; E. Gilpin, Esq.; J. H. Hichens, Esq.; Capt. F. N. Maude; R. S. Milles, Esq.; E. Muir, Esq.; M. Ratnavelacharia, Esq.; C. Wilson-Moore, Esq.

The List of Donations to the Library was read.

Mr. Whitaker called attention to the two new Survey maps of the Bournemouth district. In the map without Drift it would be observed that the boundary-lines were more detailed. In the map with Drift much new work had been incorporated—in fact, the Drift-lines were wholly new. The work had been done by Mr. Clement Reid.

The following communications were read:—

1. 'On the Occurrence of Radiolaria in Chalk.' By W. Hill, Esq., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

2. 'The Crush-Conglomerates of the Isle of Man.' By G. W. Lamplugh, Esq., F.G.S.; with an appendix by W. W. Watts, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

3. 'The Chalky Clay of the Fenland and its Borders: its Constitution, Origin, Distribution, and Age.' By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

4. 'On the Occurrence of *Spirorbis*-Limestone and thin Coals in the so-called Permian Rocks of Wyre Forest; with Considerations as to the Systematic Position of the "Permians" of Salopian Type.' By T. Crosbee Cantrill, Esq., B.Sc. Lond. (Communicated by Walcot Gibson, Esq., F.G.S.)

The following specimens were exhibited:—

Microscope-sections of the Melbourn and other Radiolarian Rocks, exhibited by Messrs. W. Hill, F.G.S., and A. J. Jukes-Browne, B.A., F.G.S., in illustration of their paper.

Rock-specimens, photographs, and microscope-sections, exhibited by Messrs. G. W. Lamplugh, F.G.S., and W. W. Watts, M.A., F.G.S., in illustration of their paper and appendix.

Rock-specimens, etc., exhibited by T. C. Cantrill, Esq., B.Sc. Lond., in illustration of his paper.

Geological Survey Map, Sheet 329 (New Series), country around Bournemouth; copies with Drift and without Drift; exhibited by the Director-General of H.M. Geological Survey.

ADMISSION AND PRIVILEGES

OF

FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

Every Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribution paid by Fellows is Two Guineas, due on the 1st of January in every year, and payable in advance; but Fellows elected after the month of February are subject only to a proportionate part of the Contribution for the year in which they are elected; and Fellows elected in November or December pay no Contribution for the current year. The Annual Contribution may at any time be compounded for by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes of the Quarterly Journal of the Society that may be published after their election, so long as their Annual Contributions are paid; and they may purchase any of the publications of the Society at a reduction of 25 per cent. under the selling prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (except during the first two weeks of September), and on Meeting days until 8 P.M.: see also next page. Under certain restrictions Fellows are allowed to borrow books from the Library.

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THE GEOLOGY OF NEW ZEALAND. Translated by Dr. C. F. Fischer, from the works of MM. Hochstetter and Petermann. With an Atlas of Six Maps. Fellows may purchase one copy of this book at Two Shillings; additional copies will be charged Four Shillings. [Postage 5*d.*]

CATALOGUE OF THE LIBRARY, 1880. (620 pages 8vo.) Price 8*s.* 0*d.* To Fellows 5*s.* 0*d.* [Postage 6*d.*]

GEOLOGICAL LITERATURE added to the Geological Society's Library during the half-year ended December 1894. (58 pages 8vo.) Price 2*s.* [Postage 1*d.*]

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[No. 205 will be published on the 1st of next February.]

[The Editor of the Quarterly Journal is directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

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